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# ESN INFORMATION BULLETIN

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This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large.

Commanding Officer . . . . . CAPT Victor L. Pesce, USN  
Scientific Director . . . . . James E. Andrews  
Editor . . . . . Ms. Connie R. Orendorf

## ACOUSTICS

- Building Acoustics Research at the Fraunhofer-Institut für Bauphysik . . . . . David Feit 1**

Germany leads in building acoustical technology R&D. This article focuses on a laboratory dedicated to improving acoustical environment of both commercial and residential buildings.

- Undersea Defense Technology Conference and Exhibition . . . . . David Feit 3**

This meeting focused on unclassified scientific and technological information related to the underwater environment. This information is especially useful as we continuously develop the world's oceans for oil, minerals, and food.

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# ACOUSTICS

## Building Acoustics Research at the Fraunhofer-Institut für Bauphysik

by David Feit. Dr. Feit is the Liaison Scientist for Acoustics and Mechanics in Europe and the Middle East for the Office of Naval Research European Office. He is on leave until January 1990 from the David Taylor Research Center, where he is a research scientist in the Ship Acoustics Department.

### Introduction

The Fraunhofer Society is an organization encompassing more than 25 separate research and development institutes located throughout West Germany. The Institut für Bauphysik is devoted to applied research in building technology--specifically, building acoustics and climate control. On a recent visit there, Professor, Dr. F.P. Mechel, the director of the Acoustics Division of the Institute in Stuttgart, was my host. The heating and climate control division shares the Stuttgart location and also has facilities in Holzkirchen.

The Acoustics Division has nearly 50 staff members with an annual budget of about 5 million DM (about \$2.5 million). Twenty percent of the operating costs and the physical facilities are provided by a subsidy from the Fraunhofer society; the remainder comes from other sources such as local and national government entities, private companies, and industry associations. The division's work is organized under two principal headings--building acoustics directed by Dr. Ing. Ertel, and technical acoustics, directed by Professor Dr. Fuchs.

### Theoretical Modeling

In my discussions with Dr. Mechel, he stressed that he is now heavily involved in the theoretical modeling of acoustical fields in various absorber configurations. In particular, we had a lengthy discussion of the mathematical approaches to be used in the modeling of sound absorption in ducts with splitters that are lined with absorbing layers. A particular problem that arises here is a determination of the complex eigenvalues for a rectangular geometry where two of the walls are coated with an absorber. The eigenvalue equation for this problem is  $z \tan(z) = b$ , where  $b$  is the normalized admittance, and  $z$  is the eigenvalue which is complex for a complex value of admittance. Although this equation looks fairly inno-

uous, it leads to an intricate solution algorithm, using a variant of the Newton-Raphson method. The same eigenvalue problem arises in several underwater acoustics applications.

In the area of room acoustics, a current major project is developing a computerized room acoustics simulation to be used in the design phase. This simulation supplements the usual ray tracing algorithms with a sound diffraction module that allows for the penetration of sound into the shadow zones that would be calculated using the usual ray tracing algorithms. A further future development is adding an electroacoustic analogue signal in the simulation. This will eventually allow a user to place an observation location anywhere in the room and experience the simulated audio signal that would be anticipated for the room by the computer simulation. The audio signal module is being developed by an Austrian collaborator. The institute is looking for a sponsor on this project since the development costs for these refinements will be quite high. This project has been in place for 2 years and grew out of a project in which the institute provided acoustical consulting for an electrical power station.

### Improved Acoustical Testing Techniques

We also discussed several projects that Mechel has initiated involving developing improved testing techniques in building acoustics. These methods when developed will be implemented at the institute and disseminated for use by others.

One of these projects is to develop improved techniques for the measurement of sound absorption in reverberation rooms. This was stimulated after a study of the large amount of scatter in the results obtained from a roundrobin series of tests at more than 20 laboratories throughout the western world--12 in the U.S. and 10 in Europe. This project has been proposed to the European Economic Community (EEC).

The first phase of this project involves using a "calibrated absorber" consisting of a honeycomb skeleton filled with a porous, foam-like absorber. In a reverberation chamber, the sound incident on the absorber will be measured as a function of the angle of incidence. Using the predetermined absorber material's absorption coefficient in its frame (based on a theoretical calculation of the reflection coefficient) and doing a numerical integration over the angles of incidence, the calibrated absorber's absorption can be calculated and compared to the measured value in the reverberation room. From this comparison, a correction factor attributed to the room can be determined. This project is now in its feasibility phase, and this institute is constructing sample calibrated absorbers and making the necessary calculations and measurements.

This project has been discussed with some 15 independent laboratories throughout the EEC. The objectives are twofold. These are--the construction and acceptance of a set of "calibrated absorbers," and the determination of a set of correction factors for specific reverberation rooms.

Another project is to develop measurement and evaluation procedures for full-scale noise barriers which is being conducted as a collaborative project with the French. The idea here is to use impulsive (transient) sources in an attempt to separate reflected, transmitted, diffracted, and absorbed components out of the resultant signal after it has reached the noise barrier using time windowing. The French are planning to use an impulsive source putting out a signal of 2-msec duration *in situ* in a high background noise level. The German approach will attempt to use Gaussian modulated impulses. This type of source signal has already been used to evaluate the performance of absorber wedges, and they have been successful in this effort up to 4 kHz. The French agency is Centre d'etudes de Batiment et Travail Publique (CEBTP).

The last of the measurement projects is concerned with measuring and evaluating enclosures for machinery noise reduction. During the early 1980's, Istvan Ver, BBN Laboratories, Inc., Cambridge, Massachusetts, came to the institute and studied the different sound fields existent in an enclosure dependent on the aspect ratio of the enclosure relative to the machinery source. These theoretical concepts will be used to develop a test method as a basis for standardization and will be a co-operative effort with TNO Delft in the Netherlands.

The institute also has the usual test facilities of a modern acoustical laboratory such as reverberation rooms, transmission loss testing chambers, and an anechoic room. There was one facility that I had not seen anywhere else and this was a full scale test chamber that had an enclosed balcony type room outside the reverberation room and this was enclosed in an anechoic room in which traf-

fic noise could be simulated. As Professor Mechel described it, balconies are very popular in Germany but traffic noise can be so intrusive and annoying that they are researching ways to prevent its transmission into the home.

## Product Development

Over the years, several industrial products have grown out of the work at the institute. One is a leak detection system using the principals of correlation analysis. The requirements for such a system are to determine if a leak exists and pinpoint it to a specific location. In the system developed here, two hydrophones are placed in a linear system such as a pipeline. Using known signals in the line, the sound propagation speed through the line is determined. If known discontinuities such as bends and branches exist, their effects are eliminated using computer simulation. With the propagation speed known, the two hydrophones are placed at opposite ends of a length of pipe where a leak is suspected. Using auto- and cross-correlation of the two signals, the precise location of an unwanted discontinuity can be determined.

Using this method, they have been able to detect leaks as small as 20 liters per minute with a localization precision of plus or minus one meter. This product developed at the institute is now licensed to a private company who provides the service on a commercial basis.

Another product that has grown out of the research at the institute is the nonporous sound absorbers. There is a great need for such a product where there is concern about the hygienic factors of any sound-absorbing system such as in food processing facilities. Conventional absorbers are usually porous and permit the intrusion of biological matter which can foster bacterial growth. The nonporous sound absorbers use the principle of acoustical resonance where the resonant system is formed by a thin membrane overlying an enclosed volume of air which provides the spring element of a mass spring system. These systems are made broad band by membranes. The DELTA Sound Absorber has several designs and is produced and licensed by DORKEN schutz Werte, Ewald Dorken AG.

## Summary

This institute, devoted to improving the acoustical environment in both commercial and residential buildings, has successfully marketed its techniques and approaches not only in Germany but throughout the world. Several investigators from other countries have studied and worked with Professor Mechel, and the institute is well represented in international standards organizations. Germany is a world leader in developing new technologies and this institute, with its modern and new facilities, is maintaining this tradition in the building acoustics realm.

# Undersea Defense Technology Conference and Exhibition

by David Feit

## Introduction

The first Undersea Defense Technology Conference and Exhibition was held in London, U.K., 26-28 October 1988. This was the first in what is hoped to be a series of yearly events devoted to the presentation and dissemination of unclassified scientific and technological information related to the underwater environment. Because much of the research conducted in this field is generally considered to be classified, meetings of this type are most welcome since they provide glimpses of scientific progress being made in government laboratories and defense-related industries to those outside such institutions. Such information is especially useful now because of the wide-ranging civil interest in the underwater environment as we continually develop the world's oceans for oil, minerals, and food.

The conference organizers brought together an international committee of distinguished scientists and engineers representing academia, government, and industry who assembled a program of some 99 papers. The papers came primarily from the U.K., but there were contributions from France, West Germany, Italy, the Netherlands, and the U.S. Because of the large number of papers accepted for presentation, the papers were given in three parallel sessions during each of the 3 days of the meeting. In conjunction with the conference, an exhibition of technical products was displayed by representatives of more than 130 companies from seven different countries.

There were multiple sessions covering a wide range of topics including:

- Environmental and civil applications, numerical methods in propagation, sea floor acoustics, and ocean sensing
- Sonar arrays, transducers, and systems
- Platforms, human environment in submarines, maneuvering and control, platforms and structures, propulsion, and weapon systems
- Noise- and vibration-reduction techniques, control of machinery vibration and noise, and radiated noise
- Underwater ranges and ranging techniques.

In my review of the meeting, I shall begin with a summary of the keynote address and then concentrate my discussions on the contents of those presentations related to underwater acoustics propagation, sonar systems, and noise- and vibration-reduction techniques.

## Keynote Address

Sir John Mason, formerly Director-General of the U.K. Meteorological Office, and currently Chairman of the Coordinating Committee on Marine Science and Technology, spoke on the observation and prediction of ocean weather systems. Knowledge of such systems is of great interest to underwater acousticians because they carry with them temperature and density gradients, stratified layers, and turbulence. These produce amplitude and phase fluctuations in acoustical signals resulting in a less than ideal environment in which to make acoustical detections or use underwater communication techniques.

Ocean weather systems are coupled with atmospheric weather systems, and the understanding and prediction of natural and/or man-made climactic changes require study of the oceans, atmosphere, and sea ice as a combined global system. With this as background, Mason described the World Climate Research Programme that has been initiated, a major component of which is the observation and modeling of the oceans on a global, three-dimensional (3-D) scale. The observations are to be used in models running on some of the world's fastest supercomputers. From the coupling of the global ocean model with its atmospheric counterpart, we will hopefully be able to simulate smaller scale features such as fronts and eddies ultimately leading to better predictions of the propagation and attenuation of acoustical signals and improved discrimination from background noise.

## Underwater Acoustic Propagation

M.B. Porter, NATO Saclant Research Center, La Spezia, Italy, began the session on Environmental and Civil Applications-Numerical Methods of Acoustic Modeling with a review paper on the subject. He surveyed the approaches used for steady state propagation modeling, namely: ray tracing, normal modes, FFP methods (fast field program which uses a fast Fourier Transform algorithm applied to the spatial transform), and the PE (parabolic equation) method. For each of the approaches, examples of the types of results that can be obtained were shown. The new work that was discussed related to the use of the above approaches to the transient signal problem. An attendee questioned the utility of the sophisticated mathematical modeling given the imprecision with which the environmental data are known.

A French approach to the problem called the *PARQUES model* was presented by B. Grandvuillemin,

GERDSM/DCN, Le Brusc, France. This uses a parabolic equation approximation to the range-dependent Helmholtz wave equation. The usual parabolic equation introduces unacceptable errors when the radiating source angular aperture exceeds 15 degrees. The model discussed here uses a quadratic development of the propagation operator presumably allowing the extension of the parabolic approximation to apertures in the range of 35 degrees. The model has been applied to problems with rectilinear, horizontal, and oblique interfaces between two fluid media. In the last part of the presentation, numerical simulations using the PARQUES model are compared to experimental results from PROPA 86--an exercise conducted jointly with the U.K. and the Netherlands in the Northeastern Atlantic. There was acceptable agreement between experiment and theory. Current efforts are being directed to reducing the computation time, developing a 3-D model, and including shear effects in the ocean bottom models.

For the last presentation of this session, P. Schippers, Physics and Electronics Laboratory-TNO, the Hague, the Netherlands, talked about the propagation loss model Acoustic Loss Model for Operational Studies and Tasks (ALMOST) for range independent environments. This model, developed in the Netherlands between 1980 and 1987, was first intended for operational use in deep water, but has now been extended for shallow water conditions. The model uses analytic ray solutions based on stylized versions of the sound speed profiles (SSP). The SSP is smoothed over a depth corresponding to seven acoustical wavelengths. The SSP's are classified into one of seventeen different types for each of which a small number of propagation modes is selected. For example, the propagation solutions are based on eigenray solutions for the bottom surface path and caustics in channels and ducts. The basic solutions are refined by submodels that account for diffraction, bottom loss per bounce, and several acoustical effects of surface scattering. Examples were shown of broad band comparisons of ALMOST generated data with measurements using underwater explosion generated signals in the 25- to 5,000-Hz range, and good agreement was noted for deep as well as shallow water. The results of this program are used in an operational mode and the exchange of information with the Dutch fleet users is reportedly very good.

In my review of the 1988 IMACS meeting held in Paris, I commented on the lack of European contributions reported at that meeting in the area of computational acoustics, especially as applied to underwater propagation problems (ESNIB 89-03:1-3). I attributed this to the applied and almost classified nature of the work and that particular forum was perhaps not the most appropriate one in which to present such work. The work presented at this meeting bears this out, while at the same time

brings some of this work out into the open and indicates where such activity takes place.

## Sonar Transducers

Several papers on the design of sonar transducers were presented. In the first contribution, G.H. Ash and G. Bromfield, Admiralty Research Establishment, Portland, U.K., described the principles of the flextensional transducer which is a resonant device for producing high power, low frequency, underwater sound. The power output of low frequency sound sources is proportional to the fourth power of frequency and to the second power of displacement. To maintain reasonable power output, the displacement must increase substantially as the frequency is decreased, and the flextensional transducer makes use of mechanical amplification to achieve this. The particular embodiment discussed here takes the form of an elliptical cross section cylindrical shell driven internally by a stack of piezoelectric ceramics oriented to drive the shell along its major axis. Small displacements along this axis produces large transverse displacements along the surface of the shell. The performance goals of the transducer and the engineering design solutions were presented.

D. Boucher, GERDSM/DCAN, Toulon/Le Brusc, France, also talked about the design and modeling of low frequency sonar projectors. Because of the size and weight of low frequency transducers, the French claim to use sophisticated computer techniques in order to optimize their design. To deal with such problems, the computer program ATILA has been developed and used. The program was simply described as a finite element program, and examples of two types of projector designed using it were discussed. These were a TONPILZ and a flextensional type. The program accounts for the fluid loading interaction forces acting on the transducer as a result of its coupling with the fluid. The fluid is also modeled using a finite element formulation. To account for the infinite extent of the fluid, a spherical surface is assumed to surround the configuration and an *appropriate boundary condition* is assumed on this surface. The difficulties inherent in such a choice and its effects on the solution were not discussed in this forum. Improvements to the ATILA code are currently being investigated. These include improved modeling of material losses, the creation of new elements, such as composite and magnetostrictive elements, and most significantly, a reformulation of the radiation problem. For the latter, they are investigating the use of a Helmholtz integral formulation for the acoustical pressure field. This essentially represents the fluid pressure as an integral form and reduces the fluid pressure-structure interaction problem to an integral equation whose numerical solution allows for a reduction in the number of unknowns to be solved for. However, this is accomplished at the cost of substantially

increasing the complexity of the final reduced number of equations to be solved.

This session concluded with a presentation by P. Cal-lard, METRAVIB, Ecully, France, who talked about a new generation of smart underwater sensors. The most significant problem for hull-mounted sensor systems is the proximity of the sensing elements with their noisy environment caused by both flow noise and hull vibrations. Without giving details, the general techniques for reducing the unwanted dynamic noise problems were discussed.

In a later poster session, more specific details related to the above topic were presented by B. Fromont, M. Josserand, and B. Tocquet, THOMSON-SINTRA ASM, Valbonne, France, in a paper discussing the advantages of thin film polyvinylidifluoride (PVDF) technology for flank arrays. In such configurations, the arrays are mounted directly to the hull. The large spatial extent of these thin film hydrophones averages over the small scale disturbances of the flow noise, thereby reducing the sensitivity of the flank arrays to such noise. Similarly, the structure-borne noise resident on the hull as a result of machinery-induced vibrations is primarily made up of flexural waves with wavelengths smaller than the typical PVDF panel dimensions. This allows for a reduced sensitivity to hull-borne noise by a mechanism similar to that discussed for the flow noise. To further reduce the machinery-generated noise component, the authors discussed active noise cancellation. In this approach, the signals from hull or machinery-mounted accelerometers are used to cancel the machinery tonals from the total hydrophone output, again offering a vast improvement in self-noise reduction for hull-mounted arrays. In their conclusion the authors state that such arrays offer a self-noise reduction that can exceed 40 dB.

## Noise and Vibration Reduction Techniques

There were three sessions devoted to this topic, and the presentations included discussions of both passive and active techniques. B.J. Dobson, Institute of Sound and Vibration Research, University of Southampton, U.K., discussed the application of vibrational power concepts to machinery-induced structure-borne noise on ships' structures. Mechanical vibrations generated by machinery have several detrimental effects, one being far field radiated noise detectable by hostile sensors and another, interference with own ship detection systems. In ship-silencing applications, one is always looking for new and better ways to identify possible noise sources. This paper discussed the progress made in this area using the notion of vibrational power transmission. The measurement and use of vibrational power concepts offers the potential of ranking and identifying the different paths and mechanisms according to their relative contributions

to the overall behavior. Rather than leave the audience with the impression that this approach offers a panacea to solving shipboard vibration transmission problems, the authors very wisely remind the listeners that the concepts presented are difficult to realize in practice and presently are applicable to the simplest of structural configurations only. The paper used a tutorial approach by presenting the basic definitions then showing illustrations of experimental data taken from measurements on ideal laboratory type structures such as beams and plates. To do measurements on more practical structures introduces a number of complications and the author presented a few general guidelines to explain how such measurements are accomplished. The ideas presented in this paper were rather fundamental and generally well known to specialists in the field. However, it did introduce the nonspecialists (and I assume there were many) to some of the difficulties that might be encountered.

The Dutch contribution by J.G. van Bakel and H.F. Steenhoeck, Ship Acoustics Department, TNO Institute of Applied Physics, the Netherlands, reviewed the use of reciprocity measurements as a measurement tool for developing transfer functions for sound radiated by ships' structures into the surrounding water. This approach has been under development at this laboratory for more than 20 years and is based on practical concepts first discussed by ten Wolde and others (ten Wolde, 1973), (ten Wolde, et al, 1975). Of course, there were many other investigators who pointed out the uses of reciprocity in mechanical systems, but this laboratory has played a pioneering role in its implementation for shipboard applications.

As an example, if one wanted to determine the sound radiated by a piece of machinery modeled as a force generator situated at a specific location on a ship, one could perform either of two experiments. In the first, the *direct* experiment, one would shut down all equipment, turn on the force generator, and measure the sound radiated into the water directly. In a practical application, this procedure might not be too easy to perform, considering the rather cramped machinery room spaces on a ship and the difficulties of mounting a shaker (force generator) with sufficient output to overcome the background noises at the original machinery location. We then can consider the *reciprocal* measurement which in this case would consist of placing a nondirectional sound projector at the points in the water where the transfer function is to be determined, and we also place a triaxial set of accelerometers where the machine is attached to the hull. It can be shown that the transfer function between the pressure and the force that would have been determined in the direct experiment is related to the acceleration per unit volume output of the sound projector in the reciprocal measurement. The particular acceleration output used is determined by which of the three possible force

transfer functions desired. The authors concluded this talk with a discussion of some of the organizational problems associated with using such measurement techniques on a full-scale ship.

The traditional technique for controlling vibration in ship's structures has been damping. E. Parker, Plessey Naval Systems Limited, Templecombe, U.K., discussed the concept of *tuned* dampers to augment the effectiveness of damping treatments. This is achieved by adding a mass layer overlaying the elastic layer and then selecting the appropriate values of layer stiffness, damping, and mass properties to optimize the effectiveness. This particular implementation in which the damping properties are distributed over an extent of surface area is called Auxiliary Mass Damping (AMD) tiles. Parker then discussed the optimization procedure introducing the pertinent equations describing the AMD tile performance. He also discussed some experimental results performed on a scale model ribbed cylinder. Although details of the model were not presented, I believe the model used was the same or similar to the one discussed in an earlier article I had written entitled "Structural Acoustics Research At Plessey Naval Systems" (ESNIB 89-04:4-5). Using an artificial vibration generator, the comparative vibration response of the treated and untreated cylinders were measured and compared. Two types of data presentation were shown. These were (1) the traditional one showing transfer inertance measurements, with and without damping, and (2) frequency-wave number spectra, also with and without damping. The latter measurement was accomplished using an array of accelerometers placed around the circumference of the cylinder, and the results clearly show the high spatial decay rate of flexural waves in the region where the AMD tiles were installed. He concludes that loss factors exceeding 0.1 can be achieved using these tiles, thus making such treatment particularly attractive for ship applications.

C.F. Ross, Topexpress Ltd., Cambridge, U.K., talked about applications of active control techniques applied to machinery mounted on oil rig platforms to protect the occupants of nearby sleeping quarters. Extra isolation can be achieved using double mounting arrangements, but because of flexibility in the mounting platforms, the effectiveness of this isolation can be nullified. To overcome this shortcoming, active vibration isolation is recommended and the underlying mathematical theory and design principles are presented. This paper, like several others with obvious classified applications, was understandably a bit

short on specific details. R. Kinns YARD Ltd., Glasgow, U.K., presented another general paper on a similar subject. In this talk, Kinns emphasized the complementarity of the two approaches--passive and active control--to cover the entire frequency range of interest.

The last paper on which I wish to make specific comments on was that by I.G. Harrison, Vickers Shipbuilding and Engineering Ltd., U.K., in which he discussed the practical aspects of machinery noise control. Harrison described the procedures used by the Noise and Vibration Engineering Department (NAVED) for diagnoses of problems and noise reduction purposes. The procedures outlined are those to be expected and include pre-installation testing of prototype and production machines, both main propulsion and auxiliary, modal testing of machinery platforms and foundations, and dockside testing. One of the more unique approaches discussed was the use of a *hydrophone necklace*--a string of hydrophones that can be wrapped around the circumference of a surfaced submarine and sequentially moved through a number of longitudinally displaced locations allowing the mapping and localization of a noise problem.

## Conclusions

This meeting is a major event in the recording of information in an unclassified forum on undersea defense technology. Even though very little real substantive information was released, it is useful to see where and on what types of systems studies are being made. The presenters gave good evidence of their familiarity with the subject matter and the most up-to-date techniques. Of course, there is a great deal of overlap between the uses of this technology by the civilian and military sectors. I think this meeting was useful in allowing the former a glimpse of the developments that they might not be typically aware of. If future meetings in this series are held, I would definitely recommend that the U.S. be represented at least as observers.

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# British Institute of Acoustics Conference--Spring 1988

by David Feit

## Introduction

The British Institute of Acoustics (IOA) like its U.S. counterpart, the Acoustical Society of America (ASA), typically holds two meetings per year. On April 5-8, 1988, the spring meeting was held at the Queens College of the University of Cambridge, Cambridge, U.K. Of the approximately 200 delegates, most were British, but there were 13 other nationalities represented including the U.S. France and the Netherlands sent the next largest number of delegates with approximately 25 percent from other European countries. The organizer and chairman of this meeting was Professor J.E. Ffowcs-Williams, Cambridge University.

The IOA differs from the ASA in that it has available for each meeting preprints of most of the papers presented in the form of a multivolume set of proceedings (Proceedings of the Institute of Acoustics, Vol. 10, Part 2, pp. 1-876, 1988). The proceedings are available from the Institute of Acoustics, 25 Chambers Street, Edinburgh EH1 1HU. This is an excellent policy, but I believe one which would be very difficult to implement for the size of meetings held by the ASA. I have recently learned that the authors can submit their manuscripts up to 3 or 4 weeks before the meeting and still have them published in the proceedings. This undoubtedly puts a tremendous burden on the Institute staff responsible for the publication. The length of the papers must be restricted, so many authors submit more detailed and complete versions of their work to other journals such as the *Journal of Sound and Vibration*.

The IOA presents several awards each year. At this meeting, the Rayleigh Medal, the major and oldest award of the IOA was presented to Professor D.G. Crighton, University of Cambridge. I will discuss the Rayleigh Lecture entitled "Fluid Loading: the Interaction Between Sound and Vibration" in more detail later. The A.B. Wood Medal, given annually preferably to an ocean acoustician, was awarded to Dr. V.F. Humphrey, University of Bath, Bath, U.K., who spoke on "Applications of Parametric Acoustic Arrays in Laboratory Scale Experiments." Dr. D.F. Walton, Admiralty Research Establishment, Portsmouth, U.K., gave the R.W.B. Stephens Lecture on "Sonar Ichthyology."

The invited plenary lectures were truly international in character. Each of the three plenary lectures was presented by non-British speakers. Dr. L.L. Beranek, BBN Inc., Cambridge, Massachusetts, spoke on "Concert Hall Acoustics: 25 Years of Experience;" Professor

L. Cremer, Technical University, Berlin, Federal Republic of Germany (FRG), lectured on "The Synthesis of the Sound Field Excited by a Rigid Body of Arbitrary Shape in Air with an Arbitrary Distribution of Normal Velocities by Spherical Sound Fields;" and the final lecture was delivered by S.M. Candel, Ecole Centrale, Paris, France, who spoke on the "Interactions Between Acoustics and Combustion."

The IOA is a member society of the Federation of Acoustical Societies of Europe. Although the attendance at the IOA meeting was smaller than a typical ASA meeting, the quality of papers and the lively discussions make it seem apparent that acoustics is thriving in the U.K. because of the IOA.

The technical categories in which papers were presented included

- Musical acoustics
- Architectural acoustics
- Codes of practice and legal matters
- Environmental noise
- Road and vehicle noise and vibration
- Active control
- Physical acoustics
- Structural transmission
- Turbomachinery and propeller noise
- Fluid loading and flow noise
- Propeller and jet noise
- Thermoacoustics.

Aside from the plenary and invited lectures, there were several parallel sessions. Therefore, I have concentrated my attention in this report to a limited number of sessions and papers, specifically those dealing with structural acoustics and active control. One should not conclude that the other papers were any less interesting, but simply there is not enough time and space.

## Structural Acoustics

Although the total number of papers presented in this area was relatively limited, the quality and significance were most impressive. This was especially true of the Rayleigh Lecture presented by Crighton. In it, he gave an excellent tutorial on the effects of fluid loading on the vibrational and radiational characteristics of elastic plates. Such applications are manifold in marine engineering, e.g., vibrations and radiation from ships and submarines, and the vibrations of stationary structures such as oil rigs and submerged pipelines, with many others from acro-

nautical and mechanical engineering. Crighton has been involved in some of the pioneering work in this field wherein the fluid medium is considered to be motionless, and in recent years he, together with some of his students, has also been studying those cases where the fluid is considered to be in bulk motion over the vibrating structure. He first discussed the governing equations, introduced the basic nondimensional parameters, and then discussed the basic characteristics of the solutions. Where closed form or explicit solutions are not available, he presented the useful asymptotic solutions from which one can ascertain the basic physical mechanisms involved in the vibration and radiation phenomena.

From this, he went on to discuss the case of periodically reinforced structures in the presence of fluid loading. This is a complication or variation of the basic common structural configuration found in the engineering structures mentioned earlier. In certain ranges of the system parameters, especially in the absence of fluid loading, unattenuated propagation of the structure-borne vibration energy along the structure occurs; while in other ranges, only evanescent wave motion (exponential decay with distance) ensues. The latter effect is sometimes referred to as *Anderson localization*, a concept probably more familiar to solid state physicists. This phenomenon is related to the localization of wave motion caused by disorder in what would usually be considered a periodic structure. In his famous study (Anderson, 1958), Anderson demonstrated that electron eigenstates in a disordered solid can be localized, thus inhibiting electric field conduction in some metals. The application of interest to structural engineers is the localization of vibrational energy to specific areas of a structure with little transmission of energy to remote regions.

The applications of this phenomenon to engineering has recently received much attention (Hodges, Power, and Woodhouse, 1985a,b), (Pierre, and Dowell, 1987), and (Keane, 1988). In his own study (Crighton, 1984), Crighton has looked at this phenomenon when the periodically framed structure is subjected to fluid loading. Crighton has shown that even in cases where attenuation in propagation would have been expected for the structure in vacuo, the effect of the fluid loading produces acoustical radiation at each inhomogeneity (rib location), thus producing an energy path through the fluid medium. The latter nullifies the so called *stop band*; i.e., that range of frequencies where energy is localized to a region in the vicinity of the excitation. Crighton concluded this part of his discussion with the notion that fluid loading invokes a mechanism that obviates the localization phenomena seen in solid state physics applications.

The final area covered in this lecture concerned the effects of mean flow on the vibration characteristics of elastic vibrating plates. Here he shows that under certain conditions the driver of the plate is actually being driven

by the system and absorbing power from it, rather than supplying power.

What remains to be done is to refine and extend the problems discussed here to slightly more complex situations closer to the practical realization. However, the question remains as to whether one should devote more attention to the asymptotic type of analysis considered here or to invest more effort in the vast array of computational procedures under current development.

J.F.M. Scott, Topexpress Ltd., Cambridge, U.K., gave a very good paper about the dispersion curves for a fluid loaded cylinder. Just as in the case of a plate, the presence of the fluid introduces an acoustical field that alters the phase speeds of the structural waves. In the case of a cylinder governed by simplified structural theories (these are appropriate for the frequency range in which the structural wavelengths are larger than the thickness of the shell), there are essentially three types of structural waves for each circumferential harmonic. These can be labelled as the quasi-flexural, quasi-longitudinal and quasi-torsional waves. These labels refer to the limiting behaviour of the waves as the frequency or the radius of curvature of the cylinder increases. In this paper, Scott presents a detailed discussion and graphical description of the dispersion curves for these waves. He notes that what I have referred to here as the quasi-flexural wave always has a real phase speed for frequencies less than the flat plate coincidence frequency, and at very low frequencies in the axisymmetric case has a phase speed close but slightly less than the sound speed of the ambient fluid. This paper did not appear in the proceedings, but has recently been published elsewhere (Scott, 1987).

The U.S. contribution in this field was presented by D.M. Photiadis, David Taylor Research Center, Carderock, Maryland, who discussed the scattering of sound from finite plates. He has treated both baffled and unbaffled plates in his analysis. The formulation used by Photiadis reduced the problem to the solution of a boundary integral equation on the scattering surface. This was then solved numerically by discretization wherein the unknown surface pressure is represented as a piecewise continuous function leading to a linear set of algebraic equations. This paper in a more complete version has also been recently published (Photiadis, 1989).

## Active Control

The meeting included a number of sessions devoted to active control although many of the papers presented were not included in the proceedings. Much of the work in this area discussed at this meeting seemed to originate from two principal sources. These were the University of Southampton Institute for Sound and Vibration Research, and two institutions in Cambridge--the University of Cambridge and Topexpress Ltd. The group at South-

ampton seems to be concentrating their efforts on the active control of sound fields within enclosed environments. This of course would have great commercial payoff as it is applicable to aircraft fuselages and car or truck interiors. In fact, the first two papers dealt with precisely these two subjects.

The first paper of the session by A.J. Bullmore, P.A. Nelson, and S.J. Elliot, presented models for evaluating the performance of propeller aircraft active noise control systems. In this paper, they used highly idealized theoretical models to analyze the potential performance of active control systems. These models compared favorably to measured results. With this in hand, a system was developed for the British Aerospace Corporation 748 cabin to reduce interior noise levels at the propeller blade passage frequency and its first harmonic.

W.R. Hodson, Topexpress Ltd., Cambridge, U.K., discussed active noise control in the interior of a saloon (sedan) automobile. The system being designed will reduce the noise at twice the engine rotation frequency (2E noise). This can be considered to be relatively low frequency noise. For a typical four-seat sedan, the maximum engine speed is less than 6,000 RPM which yields a 2E frequency of 200 Hz.

A note in the British press (London Times, February 10, 1989, p.2) indicates that both of the two projects discussed here have been successfully implemented. I will follow up on this report in much more detail in a future issue.

The latter two papers dealt with the active control of noise fields, but active control can also of course be used to alleviate vibrations. R.J. McKinnell, University of Cambridge, Cambridge, U.K., talked about active vibration isolation by canceling bending waves. To a nonspecialist in this particular field, such as me, this seems to be inherently simpler to achieve because of the dimensionality of the problem. In this case, the disturbing force, in the form of a broadband driven exciter, was applied near the fixed end of a cantilever beam. Six db of vibration reduction over a 200-Hz band was achieved experimentally, and good agreement between experiment and theory was demonstrated. The dispersive nature of flexural waves precluded the use of a simple feedforward compensation

controller. Instead, the optimum controller was derived from measured data.

There was one non-British contribution in the area of active control by G. Billoud and M.A. Galland, Laboratoire de Mecanique des Fluides et Acoustique, Ecole Centrale de Lyon, Ecully, France. The topic was the use of real time recursive filters to active control in finite length ducts. Because of the finite length of the duct, an infinite impulse response controller (IIR) is required. Between 10 and 20 db of broadband noise attenuation is achieved in this application to a laboratory air system, while 10 db of attenuation was achieved in a water-filled duct. The authors conclude that IIR filtering is particularly useful in systems where there is significant feedback between the canceling source and the detector, or where there is a high standing wave ratio such as in the water-filled duct.

## Conclusions

This meeting with its many top quality papers and invited lectures demonstrates that the IOA is an important player in the world of acoustics and gives evidence that British and European investigators are in the forefront of acoustical knowledge. In fact there are some fields, notably active control, where it is my impression that they are even more aggressively forging ahead of their American counterparts.

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# BIOTECHNOLOGY

## Biological Sciences in Norway

by Claire E. Zomzely-Neurath. Dr. Zomzely-Neurath has been the Liaison Scientist for Biochemistry, Neurosciences, and Molecular Biology in Europe and the Middle East for the Office of Naval Research European Office. She was on leave until July 1989 from her position as Director of Research, the Queen's Medical Center, Honolulu, Hawaii, and Professor of Biochemistry, University of Hawaii School of Medicine.

### Introduction

Government support of basic research in the biological sciences is limited according to the scientists with whom I met on a recent liaison visit to Oslo University and to Bergen University. This situation is in marked contrast to other Scandinavian countries such as Denmark and Sweden that receive fairly extensive support of basic research not only in the biological sciences but also in biotechnology. Through an action plan with a funding of several million dollars, the government is now providing support for developing biotechnology within various fields and industries in Norway. However, biotechnology in Norway is still far behind other European countries except Spain and Portugal. A science park is now being established adjacent to the campus of the University of Oslo. Unfortunately, it will take several years before this collaborative effort between the university and industry becomes viable. Apparently, there is some resistance by industry to collaborate with university researchers.

This report deals mainly with research carried out at the University of Oslo and some information on the University of Bergen and the University of Trondheim, as well as some research institutes in Norway.

### University of Oslo

Located in suburban Blindern, the University of Oslo is the main university in Norway with about 20,000 students. The university is divided into seven faculties with the Faculty of Mathematics and Natural Sciences being the largest. A considerable portion of Norway's research potential is gathered in the Oslo region. According to the government, conditions are therefore very favorable for cooperation between the university, trade and industry, cultural institutions, and various public bodies; and the University of Oslo is playing an active role in this cooperation. A science park is being established at Gaustad,

near the university campus. The model for the science park is based on the experience of the IDEON Science Park at the University of Lund and Cambridge Science Park, U.K. Also, a unifying research foundation for the Oslo region--FOSFOR--has been established. In particular, FOSFOR will seek to facilitate and stimulate cooperation between the university and the research institutes in the science park. Innovasjonssenteret A/S has been established to facilitate greater interaction between industry and research.

According to the administration of the University of Oslo, the university is engaged in extensive international activity within the fields of research, teaching, and externally oriented work.

The Faculty of Medicine of the University of Oslo is Norway's oldest and largest medical school with about 1100 students. The university trains more than half of Norway's medical practitioners. Research there includes a wide variety of activity within many fields of medicine such as basic, clinical, and epidemiological research.

The Faculty of Mathematics and Natural Sciences represents Norway's largest center of basic research in mathematics and natural sciences with one-third of all basic research in those areas taking place there. The areas of research in the faculty span a wide spectrum from biology with such branches as ecology and marine biology to informatics and theoretical mathematics. On the whole, the research is organized within research groups, and much of the work is done within the framework of national and international projects. Today, the faculty is giving priority to research and teaching within more technologically oriented areas emphasizing

- Informatics
- Biotechnology
- Marine Biology
- Petroleum-related Geosciences
- Materials Sciences
- Hydrodynamics and Construction Technology

- Reservoir Analysis
- Technological Pharmacy.

K. Gautvik, Institute of Medical Biochemistry, and his group have been engaged in research in several areas of biological sciences with some eventual application to biotechnological products. Gautvik has authored more than 200 publications and has received several prizes for excellence in research. In addition to his position as professor, K. Gautvik heads the Group on Molecular Endocrinology at the Institute of Medicinal Biochemistry. During the past 5 years, Gautvik's research interest has been directed toward understanding the regulation of prolactin secretion and synthesis, and of the cloning and expression of human parathyroid hormone. Gautvik and his coworkers have also cloned and partly characterized a novel prolactin-related polypeptide. In their work on molecular genetics, these researchers have determined the primary structure of the parathyroid hormone gene coding sequences, using restriction enzyme mapping, hybridization analysis, and DNA sequence analysis. Gautvik and his group have also carried out site-specific mutagenesis to alter the intracellular processing of human parathyroid hormone, and constructed a series of vectors suitable for expression in *E. coli* and in *Saccharomyces cerevisiae* of correctly processed human parathyroid hormone.

Gautvik and colleagues have studied prolactin synthesis *in vivo* as well as by *in vitro* translation. They have related prolactin gene expression to the messenger RNA (mRNA) levels obtained by Northern blot analysis as well as by *in situ* solution measurements. In addition to these functional studies of prolactin biosynthesis at the protein and nucleic acid level, Gautvik and his group have unraveled the existence of a possibly new hormonal form that is related to, but not identical to, prolactin. In addition, Gautvik and coworkers have looked at how the degree of DNA methylation affects the expression of rat prolactin and growth hormone. Using azacytidine which is incorporated into DNA but can not be methylated, Gautvik and his group have shown that this drug does not only affect single genes, but is able to develop permanent new cell phenotypes by inducing extensive chromosomal alteration.

A long-standing interest of Gautvik has been to understand how acute secretion of prolactin is induced by other hormones and pharmacological agents. In this respect, Gautvik and coworkers have developed methods for receptor characterization, functional measurements of G proteins and phosphatidyl inositol metabolism and cyclic AMP formation and degradation. These research efforts are directed towards Gautvik's aim to clone and study in detail the receptor for the hypothalamic hormone thyroliberin.

The current research activities of Gautvik and his group are

#### 1. Parathyroid hormone.

a. The development and construction of new vector systems being effective in *Saccharomyces cerevisiae* and *E. coli*. The aim is to produce human parathyroid hormone as a secretory product in both systems at a high yield and correctly processed and secreted. Gautvik and coworkers work in yeast with the alpha mating factor promoter and transcription stop signal as well as using a killer toxin promoter signal which will direct parathyroid hormone secretion.

b. By using site-specific mutagenesis, Gautvik and his group have removed a proteolytic cleavage site interior in the parathyroid hormone (PTH) molecule resulting in the expected elimination of PTH fragmentation.

c. Gautvik and coworkers have used *E. coli*-specific promoter sequences and obtained correct N-terminal processing of PTH and secretion to the periplasmic space.

d. Gautvik said that the production of human PTH was assessed for authenticity by amino acid analysis and biological activity testing.

2. Action of steroid hormones--notably, estrogens, 1, 25 dihydroxy vitamin D3, and dexamethazone--have been studied on synthesis of rat prolactin and growth hormone in cultured pituitary cells. The characterization of receptors and the need for extracellular calcium have been described by Gautvik in a series of recent publications.

3. The demonstration of two mRNA species of very different molecular weight translating *in vitro* "preprolactin-like polypeptides" of distinctly different molecular sizes, that are both immunoprecipitated with prolactin antiserum. Gautvik and his group have undertaken cloning of the high molecular weight mRNA from prolactin producing cells. At present, these researchers are characterizing 12 different positive clones with restriction enzyme mapping.

4. Gautvik said that the molecular action of azacytidine on the GH cells can not only be attributed to a different state of methylation, but is probably causing a general reprogramming of gene expression in these cells resulting in permanently altered pleomorphic phenotypes.

5. Gautvik and his group have recently finished an extensive characterization of the signal systems that thyroliberin and vasoactive intestinal peptides (VIP) use for inducing prolactin secretion and synthesis. The TRH receptor has been characterized on the protein level by photoaffinity labeling and immunological visualization. Gautvik and his group have generated complementary DNA (cDNA) libraries from the pituitary gland and identified TRH receptor positive clones that are currently being analyzed.

6. Using the growth hormone gene, Gautvik and his group have recently been successful in microinjecting and expressing this gene in transgenic Atlantic salmon. In parallel work, these investigators have also isolated salmon prolactin and growth hormone to develop methods for quantitative determination.

The goal of Gautvik and his group for the coming years is to express human PTH under optimal conditions and develop a medium scale purification process. Gautvik said that their other main efforts will be directed toward cloning and expression of the TRH receptor and the novel prolactin-like "big" polypeptide. Gautvik thinks that these results will probably shed light on functional GTP-binding proteins that are associated with the TRH receptor whose signal induction systems have been of long-standing interest to him. Gautvik hopes that the transgenic salmon will be an important model system for studying the effect of multiple copies of the growth hormone gene.

The biotechnological potential of the research by Gautvik and coworkers is the use of PTH in the treatment of osteoporosis. Human PTH is one of the most important regulators of calcium homeostasis in humans, the main target organs being the osteoblasts and the kidney tubule cells. In osteoporosis there is a concomitant and parallel reduction in mineral as well as of the organic component. Therefore, the bone that is present is normally calcified, but there is too little bone per volume unit. At present, there is no effective treatment for osteoporosis except estrogen therapy which causes many side effects and other problems. In Norway and many other countries, osteoporosis is a formidable health problem that will increase as the fraction of the elderly population increases. Therefore, if PTH therapy proves to be effective in the treatment of osteoporosis, this will constitute a fairly sizeable market.

Other research areas being investigated by Gautvik and his coworkers are (1) the biochemical and physiological function of plasma kinins and kallikreins; (2) the biological effects and mechanism of actions of the hypothalamic hormones thyroliberin, dopamine, somatostatin, and VIP in prolactin and growth hormone-producing rat pituitary cells; (3) the biological effects and mechanisms of action of steroid hormones (estradiol, progesterone, testosterone, and cortisone) examined in prolactin and growth hormone producing cells in culture; (4) studies of gene expression in transgenic fish; and (5) endocrinological research related to hyperfunction of the parathyroid gland and research in relation to medullary carcinoma of the thyroid.

F. Fonnum and coworkers, Department of Biology, are engaged in studies of synaptic transmission in the nervous system. F. Fonnum is also Head of the Division for Environmental Toxicology at the Norwegian Defense Estab-

lishment. Until recently, most of the research by Fonnum and his group had been carried out at the laboratories of the Norwegian Defense Establishment in Kjeller (suburb of Oslo). However, he and his group, including graduate students, now have facilities available at the University of Oslo. One of the interesting projects carried out by Fonnum and his group has been a study of the role of astrocytes for transmitter glutamate and gamma amino butyric acid (GABA) inactivation and precursor production in the rat brain *in vivo*. Their results support the concept that astrocytes are important for transmitter glutamate and GABA inactivation and precursor production *in vivo*, and add evidence to their hypothesis that glially synthesized glutamine is an important precursor for transmitter glutamate and GABA.

K. Briseid and his group, Department of Pharmacology, have developed a rocket immunoassay of high and low molecular weight kinogens in human plasma. These researchers have also developed an assay method for Factor XII in human plasma using prekallikrein or the chromogenic peptide S-2222 as substrates.

S. Olsnes and coworkers, Institute for Cancer Research, Norwegian Radium Hospital, Oslo, are carrying out studies on diphtheria toxin. This is a protein that binds to cell surface receptors and then enters the cytosol where it inactivates elongation factor 2, thus inhibiting protein synthesis. Olsnes found that translocation of the enzymatically active part of the toxin across the plasma membrane can be induced at low pH. Receptor molecules appear to be involved in the translocation process, which also requires and inwardly directed H<sup>+</sup>-gradient and permeant ions. Transient cation-selective channels were formed during toxin entry.

J.F. Storm and colleagues, Institute of Neurophysiology, are studying temporal integration by a slowly inactivating potassium current in hippocampal neurons.

## Other Universities

Research at the University of Bergen is concentrated on microbiology, immunology, plant physiology, and DNA biochemistry. G. Knutsen and his group, Department of Microbiology, are mainly concerned with novel and more effective microorganisms that could be used in environmental pollution control.

At the University of Trondheim, research in biochemistry is directed at biosynthesis of cellulose, microbial degradation of hydrocarbons, fish technologies, and marine biochemistry, which includes polysaccharides and cultivation of marine organisms (fish and feed). G. Halmo and coworkers, Department of Microbiology, University of Trondheim, are engaged in studies of environmental microbial degradations at low temperatures. (See ESNIB 88-03:12).

Besides Tromsø University's work in medical biology, its Institute of Fisheries, devoted to enzyme technology and fish processing, is noteworthy.

Five institutes cover the fields of industrial research, environmental toxicology, and health care. Industrial research is carried out at two institutes--the Norwegian Institute of Technology (SINTEF) at Trondheim (fermentation technology), and the Central Institute for Industrial Research at Oslo (fine chemicals, microbial transformations). The Division of Environmental Toxicology of the Norwegian Defense Establishment is involved in DNA repair. In the health sector, the Norsk Hydro Institute for Cancer Research works on monoclonal antibodies for diagnostic and therapeutic use. The National Institute of Public Health is a vaccine producer and has research interests in hybridomas.

## Conclusion

Overall research in the biological sciences is much less innovative than in the other Scandinavian countries such as Denmark and Sweden. This appears to be because of the limited support of such research by the Norwegian government. As stated previously, governmental support of basic research in Denmark and Sweden is far greater than in Norway. The Norwegian government hopes that the building of the science park in Oslo will result in a better coordination of research efforts and support by industry. However, whether any improvement will take place is difficult to assess at this time. Although as mentioned in this report, some scientists are carrying out very good research, the general picture is not first rate.

# Twelfth Biennial Meeting of the International Society for Neurochemistry

by Claire E. Zomzely-Neurath

## Introduction

The twelfth biennial meeting of the International Society for Neurochemistry (ISN) was held at the Congress Center of the Hotel Alfa Mar, Albufeira, Portugal, from April 23 to 28, 1989. The participants came from 41 different countries making this a truly international meeting. Attendance was very high, about 1200 participants representing 15 West European countries and the U.K. There was an unusually large participation by scientists from six Eastern European countries as well as the U.S.S.R. compared with previous meetings of the ISN. Participants from the U.S. constituted the majority of participants which indicates that a majority of ISN members are from the U.S. There were also many scientists from Israel and Japan.

The scientific program consisted of symposia, oral communications, colloquia, roundtables, and more than 600 poster presentations. The topics covered at this ISN meeting are shown in Table 1.

There was an enormous amount of material presented at this ISN meeting with concurrent symposia and oral communications sessions. Therefore, it is only possible to present summaries of selected topics in this report. Although there were many excellent presentations by scientists from non-European countries, only the research of European scientists is included in this report because of

lack of space and also because the purpose of the ESNIB reports is to emphasize the work of European scientists. The abstracts of all the presentations are available in a special issue of the *Journal of Neurochemistry*, Volume 52, supplement from Raven Press, 1185 Avenue of the Americas, New York, N.Y., 10036.

Table 1. Meeting Topics.

Symposia	Oral Communication
Phospholipids and neurotransmissions	Gangliosides
Molecular aspects of recognition during neural development	Phosphoinositides
Functional aspects of gangliosides	Parkinsonism
Regulation of neural gene expression	Demyelination
Function of astrocytes	Excitatory neurotransmitters
Neurotropic actions of mitogenic growth factors	Alzheimer's aging
Calcium and neural function	Myelin
Neurochemistry of neurological and psychiatric disorders	Calcium
Basic and clinical aspects of excitatory amino acids	Channels
Role of protein phosphorylation in synaptic transmission	Regeneration
	Glial cells
	Ischemia
	Receptor regulation
	Neurotransmitter
	Axonal and synaptic proteins
	Seizures

## Molecular Aspects of Recognition During Neural Development

E. Bock, Protein Laboratory, University of Copenhagen, Denmark, presented an informative talk on the

structure and function of the neural cell adhesion molecule (NCAM). Bock and her coworkers have carried out extensive research on NCAM. The NCAM participates in morphogenetic processes during development and temporal changes in amount and post-translational modifications of the molecule are assumed to regulate its function. The NCAM is associated with brain membranes although a small fraction of soluble forms has also been demonstrated by Bock and her group. The amount of NCAM varies with age with a peak value at postnatal day four in the rat. In the adult brain, the level is twofold lower. The NCAM in brain is composed of three or more primary translation products. The polypeptide composition varies with age and cellular localization. Soluble forms of NCAM are found not only in brain, but also in cerebrospinal fluid, blood, and amniotic fluid. Bock said that studies on the soluble forms indicate a complex origin. A fraction is released from the membrane via phospholipase C. A second fraction is probably cleaved from the membrane via proteolytic degradation, and finally a third fraction may be secreted. The NCAM mediates cell-cell adhesion via a homophilic binding; i.e., NCAM binds to NCAM. Bock and her group have developed a solid phase assay for the investigation of the kinetics of NCAM binding to itself. Binding constants between  $10^{-6}$  and  $10^{-8}$  M were obtained depending on whether embryonic or adult forms of NCAM were used.

F.S. Walsh, Institute of Neurology, Queen Square, London, U.K., also presented an interesting and informative talk on the structure and expression of the NCAM-gene using recombinant DNA technology. Walsh said that NCAM is a cell surface sialoglycoprotein important in homophilic adhesive interactions involving neurons, glia, and muscle. Walsh and his group have found that the gene encoding NCAM is a single copy, and diversity of protein structure can be accounted for by specific patterns of alternative splicing and polyadenylation site selection. Twenty-three coding exons have now been identified and these allow the generation of four main types of NCAM in brain. These are transmembrane NCAM's with either a large or short cytoplasmic tail, a lipid-tailed NCAM, and a secreted NCAM. In addition, the lipid-tailed isoform in skeletal muscle uses three additional exons to insert a putative hinge region into the extracellular domain of this isoform. Walsh said that this region is also associated with O-linked oligosaccharide attachment. A novel soluble form of NCAM in muscle and brain is generated by a specific splicing pathway. In the extracellular region, a new exon is inserted that contains a stop codon and thus prematurely terminates the reading frame, generating a soluble NCAM. Walsh said that full length complementary DNAs (cDNA) in expression vectors are now available for most isoforms and these have now been placed in 3T3 cells to generate cell lines that synthesize different human NCAMs. This model sys-

tem in conjunction with appropriate mutant constructs should allow an analysis of the role of different regions and post-translational modifications in specific recognition events.

## Regulation of Neural Gene Expression

M.R. Hanley, MRC Molecular Neurobiology Unit, MRC Center, Cambridge, U.K., discussed the topic of proto-oncogenes in neural signal transduction in a very interesting talk. Hanley said that nerve cells respond to environmental and developmental cues by a range of short- and long-term alterations in genetic activity. Cellular genes known to have transforming potential in susceptible proliferating cells are known as proto-oncogenes, and are now candidates for discrete components of this genetic signalling process, which takes information from the cell exterior or cytosol to the nucleus. Several major classes of *proto-oncogenes* have been identified in neural populations--nuclear, growth factor-like, receptor-like, GTP-binding and kinases. Hanley discussed the possible roles of these genes in cell communication in the mature nervous system, emphasizing two specific examples--the MAS oncogene and the *ras*-related family. Hanley and his coworkers have recently provided evidence that the MAS oncogene encodes an angiotensin receptor that is enriched in brain. Functional analysis suggested that the activation of MAS by angiotensin is coupled to inositol lipid breakdown, calcium mobilization, and related events. Thus, according to Hanley, a subset of peptide receptors and the inositol lipid signalling pathways are implicated in transformation, and also in the acute regulation of genetic activity, which may be of special importance in the brain. Hanley said that the *ras* family now extends to nearly twenty discrete genes whose protein products share some common sequence similarity, and the ability to bind and hydrolyze GTP. From results obtained in yeast, it appears that members of this family may be essential elements in intracellular trafficking, mitosis, secretion, and cytoskeletal organization. Modulation of the activity or level of expression of *ras* p21 species alters levels of the bradykinin receptor and the efficacy of different signal transduction events. According to Hanley, these results suggest that the *ras* family may act as "organizers" regulating cell shape and sensitivity.

J. Mallet, Laboratory of Cellular and Molecular Neurobiology, C.N.R.S., Gif-sur-Yvette, France, spoke about recent advances in the molecular genetics of tyrosine hydroxylase (TH). Mallet and his group have already made major contributions to research in this area. Catecholaminergic systems in discrete regions of the brain are thought to be important in effective psychosis, learning and memory, reinforcement, and sleep/wake cycle regulation. The TH is the first enzyme in the pathway of cate-



cholamine synthesis. Its importance is reflected in the diversity of the mechanisms described that control its activity. The TH levels vary during development and as a function of the activity of the nervous system.

Mallet and his group are investigating regulatory mechanisms in model systems including *in situ* hybridization on tissue sections, S1 mapping experiments, and transfection in established cell lines. These researchers are devoting particular effort to identification of the cis as well as transregulatory elements involved in control of the expression of rat TH. Mallet and coworkers have shown, in humans, that a single gene encodes four messenger RNA (mRNA) species by alternative splicing. A significant difference was found between each form of the enzyme, suggesting that alternative splicing may play a role in regulating human TH activity *in vivo*.

Mallet and his group used retrovirus mediated gene transfer to introduce human TH cDNA in several cell lines. All cell lines tested produced L-DOPA efficiently. They also found that At-T20 or cell lines derived from an anterior pituitary mouse tumor synthesized dopamine whose release was stimulated by high potassium and was calcium dependent. Mallet discussed the implication of this finding in the analysis of the metabolism of catecholamines and the study of degenerative disorders such as Parkinson's disease. In addition, Mallet presented evidence that mutations in the gene encoding TH maybe important in the etiology of an autosomal dominant form of manic-depression psychosis.

## Basic and Clinical Aspects of Excitatory Amino Acids

Research on excitatory amino acids (EAA) has become an area of intensive studies by many research groups worldwide because of the potential for treatment in various neurological disorders.

At this symposium, F. Fonnum, Norwegian Defense Research Establishment, Division for Environmental Toxicology, Kjeller, Norway, discussed the topic of transmitter and nontransmitter pools of glutamate. Fonnum and colleagues examined the qualitative and quantitative aspects of the transmitter pool of glutamate in three different models: (1) neostriatum in the presence and absence of corticostriatal terminals, (2) calcium dependent potassium-depolarized release from neostriatum studied with microdialysis, and (3) comparison of included changes in neostriatum and globus pallidus. The results showed that about 25 percent of the glutamate in neostriatum belong to the synaptic pools of glutamate. The concentration of glutamate in the corticostriatal terminals was about 50 mM. A large part of the transmitter pool is taken up by a proton pump transport system and stored in the synaptic vesicles. Studies with fluorocitrate and methionine sulfoximine strongly support an important

role of glial cells in the synthesis and removal of transmitter glutamate *in vivo*. Also during hypoglycemia or hypoxia, pathological states accompanied by a decrease in ATP, a massive efflux of glutamate is expected to take place.

L. Turski, Schering AG, Berlin, Federal Republic of Germany (FRG), presented an interesting talk on excitatory amino acid derivatives. Turski said that the dicarboxylic acids, L-glutamate (GLU) and L-aspartate (ASP) are important for normal brain function. Abnormal function of EAA mediated transmission may contribute to seizure disorders, hypoxia/ischemia, hypoglycemia, brain and spinal cord trauma, anxiety, spasticity, memory impairment/dementia, schizophrenia, and chronic neurodegenerative disorders. The advent of selective antagonists for subtypes of GLU receptors, N-methyl-D-aspartate (NMDA), kainate (KA), and quisqualate (QA) receptors has generated interest into the possible therapeutic use of such compounds. The NMDA or KA/QA antagonists are likely to have antiepileptic, anxiolytic, antispastic, and neuroprotective effects but may also impair memory and cognition. Drugs designed to enhance excitatory action at NMDA or KA/QA receptors may be memory-enhancing but might also possess serious side effects, for example, be proconvulsant, be anxiogenic, induce motor impairments, and may even augment neurotoxic processes. The latest concept of a multireceptor/ionophore complex for EAA (NMDA/glycine/phencyclidine/ $Zn^{2+}/Mg^{2+}$  receptor-ionophore complex) promises a new way of dissecting the activity of EAA receptor ligands, and perhaps aiding in the design of more selective drugs with less side effects. However, the potential development of tolerance, dependence, and withdrawal in the course of chronic treatment with this class of drugs is not known. Moreover, the pharmacokinetics of EAA receptor ligands are not yet clear although the development of the first orally available competitive NMDA antagonist (CGP 37849) will help in this area. Nevertheless, Turski said that there is a high therapeutic potential for EAA receptor ligands as novel anxiolytics, anticonvulsants, muscle relaxants, memory enhancers, and neuroprotectants. A further possibility is their use in preventing the development of abiotropic diseases (chronic neuroprotective action). Turski posed the question as to how long will these prospects stay in the sphere of dreams before they become everyday realities.

M.A. Lynch, National Institute for Medical Research, Mill Hill, London, U.K., presented an informative talk on the mechanisms of long-term potentiation in the hippocampus. Lynch said that long-term potentiation (LTP) of presumptive glutamatergic pathways in the hippocampus has excited considerable interest as a plausible mechanism for the neural basis of information storage in the mammalian brain. In most excitatory pathways in the hippocampus, induction of LTP occurs when, as in tetanic

stimulation, there is a conjunction of activity in presynaptic terminals with strong dendritic depolarization. These induction conditions reflect the voltage-dependent characteristics of the ionic channel associated with the NMDA subtype of glutamate receptor. The entry of calcium through postsynaptically located NMDA channels is thought to be the initiating event in LTP.

The maintenance of LTP is less well understood and may involve both postsynaptic and presynaptic contributions. Lynch and his group have found that LTP is associated with a sustained increase in the release of glutamate which is blocked by drugs or manoeuvre that block LTP. If LTP is sustained partially by an increase in transmitter release, the question arises as to the nature of the signal that is passed from the postsynaptic site of induction to the presynaptic terminal. Lynch presented evidence suggesting that arachidonic acid or its lipoxigenase metabolites may act as such a retrograde messenger for the following reasons: (1) LTP is accompanied by a sustained increase in the release of arachidonic acid, (2) LTP is blocked by compounds that inhibit its liberation from phospholipids, (3) arachidonic acid itself produces an activity-dependent potentiation of evoked responses both *in vitro* and *in vivo*, and (4) lipoxigenase products of arachidonic acid metabolism powerfully enhance calcium-dependent release of tritiated glutamate from hippocampal synaptosomes.

J. Lehmann, Division of Neurobiology, FONTAX, Puteaux, France, discussed the NMDA receptor complex. Electrophysiological, biochemical, and behavioral approaches have all contributed to our concept of the NMDA receptor complex. Three sites in the complex have been clearly identified. Competitive agonists (e.g., NMDA) and antagonists (e.g., CPP, CGS 19755) interact with the same site as the putative neurotransmitters aspartate, glutamate, and homocysteate. Dissociative anesthetics such as ketamine, phencyclidine, and MK-801 appear to block the cation channel opened by NMDA-type receptor agonists. This cation channel is labeled in receptor binding studies by tritiated thienylcyclohexylpiperidine (TCP). A third site of modulation has been identified in electrophysiological and receptor binding studies. Glycine increases the affinity of the NMDA receptor for agonists and retards desensitization in well-washed isolated cells or membrane preparations. *In vivo*, this site appears to be completely occupied by endogenous glycine, according to Lehmann. Competitive NMDA antagonists and dissociative anesthetics produce similar, but not identical behavioral actions. Lehmann thinks that the imminent development of glycine agonists and antagonists should yield agents that possess yet another distinct set of behavioral properties.

## Excitatory Neurotransmitters

J. Drejer, Ferrosan Research Division, Soeborg, Denmark, reported on a new potent glycine antagonist FG 9067 (MNQX) that shows anticonvulsant activities. The recent demonstration that glycine acting via a specific binding site on the NMDA receptor complex is essential for the activation of the complex, has started a search for antagonists of this new glycine binding site. Recently, it was reported that NMDA antagonism by the compound HA 966 could be reversed by glycine, indicating that this compound is a glycine antagonist. Thus, Drejer and his group have reproduced these results in a model of NMDA-induced  $H^3$ -GABA release from cultured cortical neurons. In this model, a new quinoxalinedione--FG 9067 (MNQX)--was found to be a potent glycine antagonist with an  $IC_{50}$  value of 200 nM, which is around 100 times lower than for HA 966. Other compounds from the quinoxalinedione-series showed only partial (DNQX) or no (CNQX) glycine antagonism. The effect of competitive NMDA antagonists (D-APV, CPP) could not be reversed by glycine. Similarly, the noncompetitive NMDA antagonist MK 801 was insensitive to glycine. However, PCP which is believed to share the same binding site as MK 801 at the NMDA ionophore, showed an increased NMDA antagonist potency in the presence of 10  $\mu$ M glycine. Drejer and his group found that FG 9067 (MNQX) potentially blocked NMDA responses in the cortical wedge preparation and also blocked NMDA-induced spreading depression in chick retina. In both these functional *in vitro* models, the NMDA antagonism by FG 9067 (MNQX) could be fully reversed by glycine. The FG 9067 (MNQX) was also tested for anticonvulsant activity against audiogenic seizures in the DBA-2 mice. Drejer and his group found that the compound potentially blocked seizures in this model indicating that glycine antagonists have a anticonvulsive potential.

A.E. Fletcher, Department of Pharmacology, School of Pharmacy, London, U.K., reported on the modulation of NMDA receptor function in granule cells. This was a collaborative study with G.P. Wilkin, Department of Biochemistry, Imperial College, London, U.K. Fletcher said that glycine modulates NMDA receptor activation in mammalian higher brain centers. This appears to be mediated via strychnine-insensitive receptors on the NMDA receptor complex. Fletcher and colleagues have studied this role of glycine in rat cerebellum. Receptor radioautography of cerebellar sections revealed that more than 90 percent of the strychnine-insensitive tritiated glycine binding sites were localized in the granule cell layer of the cerebellum. Scatchard analysis of tritiated glycine binding to 10-micron cerebellar sections indicated a single, saturable component. Release studies from 400 micron Vibratome slices, stimulated by 55-mM potassium showed an increase of 136 percent over basal

levels at 3 minutes and 144 percent at 5 minutes. No increase was observed in the absence of calcium. Fletcher said that the data support the presence of a population of Golgi inhibitory interneurons in the cerebellar cortex that use glycine as a neurotransmitter and release this amino acid to act on strychnine-insensitive sites associated with NMDA receptors on granule cells.

J. Dunlop, Department of Biochemistry, University of St. Andrews, Edinburgh, U.K., presented an interesting report on excitatory sulphur amino acid-evoked release of transmitter amino acids from rat brain synaptosome fractions. Dunlop said that a number of endogenous sulphur amino acids (SAA's) exhibiting similar properties to GLU and ASP have been proposed as putative transmitters. To further characterize the synaptic actions of SAA's, Dunlop and his group have studied the effects of L-enantiomers and D-enantiomers of cystate (CA), cysteine sulphinate (CSA), homocysteate (HCA), homocysteinesulphinate (HSA), and S-sulphocysteine (SCC) on neurotransmitter release mechanisms in rat brain synaptosome fractions. Synaptosomes were preloaded with D ( $H^3$ ) aspartate (DASP), ( $H^3$ ) gamma amino butyric acid (GABA), or ( $H^3$ ) dopamine (DA). Release of D- ( $H^3$ ) ASP was wholly calcium-independent; L-CA, D-CA, L-CSA, D-CSA, L-HSA, L-SSC but not L-HCA, D-HSA, and D-SSC induced significant release. Both calcium-independent and calcium dependent components of ( $H^3$ )-GABA release could be induced by L-CA, L-CSA, L-HSA and L-SSC but not by L-HCA; D-enantiomers caused no release above basal efflux. No SAA-stimulated ( $H^3$ )-DA release was observed. High performance liquid chromatography (HPLC) analysis of endogenous amino acid release showed that 5 minutes stimulation with L-CSA induced both a calcium-dependent and calcium-independent release of GLU and ASP but no clear calcium-dependent release of GABA. Release of amino acid transmitters was not blocked by excitatory amino acid receptor antagonists at less than 1-mM concentrations. Fletcher said that the results imply a SAA-stimulated selective release of amino acid transmitters by mechanisms that include heteroexchange with GLU/ASP, and receptor-activated release by thermodynamic reversal of the GLU and GABA transporters and exocytosis.

## Nerve Regeneration

H.W. Müller, Department of Neurology, University of Düsseldorf, FRG, presented an interesting report on a regeneration-associated gene expressed in sheath cells of peripheral nerve. Müller and his group constructed a cDNA library with poly (A) + -RNA isolated from distal segments of rat sciatic nerve after a crush lesion. Using a differential colony hybridization procedure, specific cDNA clones were selected which were either induced or

repressed during the initial nerve regeneration process. Müller described one of the regeneration associated clones (pcD-80). The pcD-80 mRNA (approximate size of 1 kilobase) recognized in Northern blots was present in small amounts in noninjured mature sciatic nerve. In a spatio-temporal analysis, moderately increased levels of the pcD-80 mRNA (five-fold above control level) were detected in the proximal and distal stumps of nonregenerating transected and ligated nerves at 1 and 4 weeks after injury. In the distal segment of a crushed nerve, the steady state level of the pcD-80 mRNA transiently increased to at least 40 times above control at a time (1 week after crush) when axons are known to regenerate in this nerve segment. Following partial sequencing of the pcD-80, this regeneration-associated cDNA clone could not be identified by computer-assisted nucleotide sequence comparison. In order to determine the cellular localization of the pcD-80 mRNA in both tissue sections and cultured cells from sciatic nerve,  $S^{35}$ -labeled RNA probes were used for *in situ* hybridization.

M. Schwartz, Department of Neurobiology, Weizmann Institute of Science, Rehovot, Israel, presented an informative talk on the topic of glial cell modulation and central nervous system (CNS) regeneration. The CNS axons have an extremely limited ability for spontaneous growth and regeneration after injury. However, it appears that injured CNS axons can readily be induced to elongate if provided with a suitable environment.

Studies by Schwartz and his group have shown that the environment is amenable to treatment by soluble substances originating from regenerating CNS neurons of lower vertebrates (fish optic nerves). Such substances trigger regenerative growth, but limited when applied to injured nonregenerating adult rabbit optic nerves. The growth is accompanied by alterations in the surrounding non-neuronal cells manifested by laminin synthesis and accumulation. Schwartz said that a factor within these soluble substances can directly activate glial cells, *in vitro*, to produce and accumulate laminin as well as fibronectin, indicative of a more general transformation. Combining this treatment modality with low energy He-Ne laser irradiation, which postpones degeneration, cause an exuberant growth of axons that traverse the site of injury and extend (5-6cm) into the direction of the brain. Horseradish peroxidase (HP) staining revealed the retinal ganglion cell origin of the growing axons. A concrete counting of axons revealed that 8 weeks after injury, about 15,000 axons are traversing the site of the injury (5 percent of the adult optic nerve). The growing axons seemed to be supported by astrocytes. Thus, Schwartz suggested that astrocytes, in the absence of any treatment, do not form a physical barrier; instead, they are forming an amenable biochemical barrier. Further studies are in progress in an attempt to identify the amenable astrocytes morphologically and immunochemically.

## Nerve Growth Cones

D. Monard, Friedrich Miescher Institute, Basel, Switzerland, reported on cell-derived proteases, protease inhibitors, and extracellular matrix at the growth cone. Glia-derived nexin (GDN) is a 43 kilodalton (kDa) cell-secreted serine protease inhibitor with neurite promoting activity. The GDN forms sodium dodecyl sulfate-resistant complexes with urokinase, plasminogen activator, thrombin, or trypsin. Immunohistochemistry and Northern blot analysis carried out by Monard and his group indicate that GDN is abundant in regenerating structures of the nervous system. The GDN promotes neurite outgrowth in primary neurons and potentiates the effect of nerve growth factor NGF. The GDN or GDN complexed to a protease interacts with extracellular matrix components such as laminin and vitronectin. The interaction is more efficient in the case of the complex protease-GDN. The presence of GDN modulates the neurite-promoting effect of laminin or vitronectin.

Proteolytic activities have been localized at the growth cone and seem to be required for the motility of the filopodia. According to Monard, his and his group's data support the idea that GDN not only inhibits proteolytic activity at the level of some filopodia or in their vicinity, but that the resulting complex also contributes to the localized stabilization required for a net neuritic elongation.

P. Doherty, Institute of Neurology, Queen Square, London, U.K., presented an informative talk on enhanced neurite outgrowth from sensory neurons grown on monolayers of cells transfected with cDNAs encoding three distinct NCAM isoforms. Cells of differing phenotypic origin vary in their ability to support neurite outgrowth. In order to determine the contribution that individual cell adhesion molecules make in supporting neurite outgrowth, Doherty and colleagues have grown rat and human dorsal root ganglion neurons on monolayers of cells transfected with cDNAs encoding three distinct human NCAM isoforms. The L-cells and 3T3 cells were transfected with cDNAs encoding a lipid-tailed NCAM isoform common to many neuronal cells and a lipid-tailed muscle specific isoform that differs from the former in that it contains an additional sequence block in the extracellular domain. When grown for up to 3 days *in vitro*, both human and rat neurons showed extensive neurite outgrowth over the parental cell monolayers. However, Doherty said that transfected cells expressing immunoreactive NCAM at the cell surface consistently supported neurite outgrowth to a significantly greater extent. Their initial studies suggest that the ability to enhance neurite outgrowth may correlate both with the relative amount of NCAM expression, and with the type of NCAM isoform that is transfected.

## Ischemia

L. Hillered, Department of Neurosurgery, University Hospital, Uppsala, Sweden, reported on chemical changes in the extracellular fluid of human cerebral cortex during ischemia measured by intracerebral microdialysis. This was a joint project with U. Ungerstedt, Department of Pharmacology, Karolinska Institute, Stockholm, Sweden. Hillered and colleagues measured changes in the extracellular fluid (ECF) concentrations of some energy metabolites and amino acids in cerebral cortex of patients undergoing glioma surgery. A microdialysis probe (Carnegie Medicin AB, Stockholm, Sweden) was inserted in apparently normal frontal cortex (verified histologically) surrounding the glioma before frontal lobe resection, serving as a simulated ischemia model. The dialysis system was perfused with Ringer solution at a flow rate of 2  $\mu$ l/min. Samples were collected every 10 minutes before and during resection and analyzed by HPLC. The resection procedure was associated with marked increases in the ECF concentrations of lactate, hypoxanthine, inosine, and adenosine, indicating ischemic conditions. Concomitantly, the levels of EAA; i.e., glutamate and aspartate, and inhibitory amino acids; i.e., GABA and taurine, were dramatically elevated. The concentration of alanine, glycine, and tyrosine were also markedly increased, while arginine and threonine did not change significantly. Hillered concluded that intracerebral microdialysis appears to be a suitable technique for studying various physiological events in the ECF, including the role of EAA and adenosine, during conditions of cerebral ischemia in man and that frontal lobe resection may be a useful focal ischemia model.

## Axonal and Synaptic Proteins

P.W. Beesley, Royal Holloway and Bedford New College, London, U.K., presented an informative talk on synaptic-enriched glycoprotein--GP65 and GP55 as well as the molecular properties and identification of a novel striatal specific isoform. Beesley said that GP65 and GP55 are immunologically-related specific glycoprotein components of isolated synaptic membranes and post synaptic densities (GP65 only). The GP65 is localized to subsets of forebrain neuronal processes extending into the synaptic region. The novel and differing patterns of subcellular localization of these glycoproteins suggests that they play important roles in CNS function. Beesley and colleagues have now used a monoclonal antibody probe--Mah SM GP65--which is specific for these glycoproteins, to investigate the structural relationship between GP65 and GP55. Proteolytic and glycosidic degradation procedures in combination with Western blotting were used to show that GP65 and GP55 contain

similar amounts of sialic acid (5kDa), and of high mannose (5-8kDa) and complex (17-20 kDa) carbohydrate residues. Complete chemical deglycosylation results in the generation of single polypeptide bands of 40 kDa and 28 kDa from GP65 and GP55, respectively. Peptide mapping experiments confirmed a close structural similarity between GP65 and GP55. Tryptic digestion of GP65 lowers its molecular weight to 53 kDa. Both this species and GP55 are resistant to trypsin. These results suggest that the two molecules may differ substantially only by a 12-kDa polypeptide fragment which contains little if any carbohydrate. High resolution gradient gels showed that GP65 and GP55 exist as doublets. Beesley and coworkers found that striatum contains a region specific novel GP65 isoform of 69 kDa. Beesley thinks that the structural microheterogeneity of GP65 and GP55 is likely to be caused by variation in carbohydrate rather than peptide structure.

### Regeneration

P. Schotman, Institute of Molecular Biology, University of Utrecht, The Netherlands, presented an interesting talk on the enhanced expression of growth-associated protein B-50/GAP43 in dorsal root ganglia and sciatic nerve during regenerative sprouting. Schotman said that the neuron-specific phosphoprotein B-50 is identical to GAP43 and might play a role in axonal growth. The GAP/B-50 is a major constituent of the axonal growth cone and it is present in outgrowing neurites in fetal and neonatal rat brain and spinal cord.

Schotman and colleagues studied the time course of B-50 expression during regeneration of the sciatic nerve

after crush. The B-50 mRNA expression in dorsal root ganglia (DRG) was quantified by Northern blots. A linear rise in B-50 mRNA level up to 48 hours became significant at 18 hours after the crush. Subsequently, the level decreased gradually until it returned to control level at post-operative day 37. The B-50 protein levels in DRG were quantified using a radioimmunoassay. The first significant rise in B-50 protein occurred 40 hours after the crush lesion, reaching a plateau of 3 times the basal level between day 6 and day 20. Schotman said that the similarity in kinetics between B-50 mRNA and protein expression suggests a transcriptional regulation of B-50 as has been described for GPA43 during the development of the nervous system. However, B-50 immunoreactivity remained significantly elevated up to 60 days after the crush lesion, suggesting an increase in the half life of the protein as well.

### Conclusion

The topics presented in this report on the ISN meeting include: (1) molecular aspects of recognition during neural development, (2) regulation of neural gene expression, (3) excitatory neurotransmitters, (4) regeneration, (5) ischemia, (6) nerve growth cones, (7) basic and clinical aspects of excitatory amino acids, (8) axonal and synaptic proteins, and (9) nerve regeneration. Unfortunately, this represents only a small fraction of the enormous number of presentations at the ISN meeting, but space limitation did not allow for additional summaries of the sessions. I have presented only the research carried out by European scientists which clearly indicates top quality and innovative work.

# MATHEMATICS

## Stuttgart University

by Richard Franke. Dr. Franke is the Liaison Scientist for Mathematics and Scientific Computing in Europe and the Middle East for the Office of Naval Research European Office. He is on leave until September 1989 from the Naval Postgraduate School, Monterey, California, where he is a Professor of Mathematics.

### Introduction

The Universität Stuttgart is located primarily on a recently developed site at Vaihingen, Federal Republic of Germany, southwest of Stuttgart, although some facilities remain at the old campus near the center of town. I visited the Department of Mathematics at the new location, and the Department of Computer Science at the old.

### Department of Mathematics

My host at Stuttgart University was Professor Dr. Klaus Hölzig, who moved last fall from the University of Wisconsin (previously at the Mathematics Research Center, Madison). The chairman of the Mathematics Department at Stuttgart University is Professor Dr.-Ing. Wolfgang Wendland. Staffed by about 20 professors, the

department is divided into two institutes--A and B--being more or less applied and pure, respectively.

Wendland and his associates work on numerical solution of partial differential equations by the finite element and boundary element methods. For example, a recent work by student Harald Berger treats the convergence of the finite element method for transonic flow. Linear elements over a triangulation are used. The equations are formulated using the Glowinski/Pironneau method because conventional methods do not work in the transonic regime (Glowinski and Pironneau, 1978). Proof of convergence with an auxiliary entropy condition to suppress nonphysical solutions is obtained for the finite element formulation of the full potential equation (Berger, 1989).

During the past several years, Höllig has been one of a few persons at the center of the development of multivariate spline theory. The more general theory is related to simplicial subdivisions, and while elegant mathematically, do not appear to be easy to use for applications. On the other hand, for regular subdivisions the applications situation is much brighter. The mathematical theory of multivariate box-splines springs from a generalization of univariate B-splines from the point of view given by Schoenberg (1973). The starting point is with certain vector directions (assume the vectors have integer components) and the characteristic function of a set related to those vectors. Higher order splines are then built up by convolution. Integer translates of these functions are again box-splines. These multivariate splines have some nice properties, such as: Box-splines are piecewise polynomials, and for some (well defined) sets of vectors in the definition the functions are of smoothness one less than the degree, analogous to univariate B-splines. For certain sets of vectors, the smoothness is less. There are nice integration, differentiation, and recurrence formulas. The set of box-splines centered at integer translates over the plane form a partition of unity.

Unfortunately, the set of integer translates of box-splines are not always linearly independent, which makes them ill posed for interpolation. Nonetheless, with some regularizing conditions imposed interpolation is possible, and in particular, the existence of cardinal splines (those taking on the value one at the origin, zero at all other integer pairs of coordinates in the plane) which grow at most like a polynomial is assured.

There is an interesting connection between box-splines and tilings in the plane. Let  $f(x)$  denote a certain multilinear function in 2-space, whose coefficients are the vectors defining the box-spline. Consider the set  $\{x: |f(x)| < |f(x + 2\pi\alpha)|\}$ , all nonzero  $\alpha$  with integer components. This set is also the support set for the Fourier transform of  $f$ . While it was initially thought these sets would be mundane, they turn out to be rather interesting (at least from an artistic point of view). This idea is gener-

alized to a larger class of functions in deBoor and Höllig (1989).

With a few exceptions, as in computer-aided geometric design (for which their subdivision properties are useful), not very many applications of box-spline theory have been made, despite their very interesting properties (see Höllig, 1989). At the present time, a comprehensive book on box-splines is being written and should appear in 1990 (see deBoor, Höllig, and Riemenschneider).

## Institute of Parallel and Distributed Supercomputers

The Institute of Parallel and Distributed Supercomputers (Institute) is directed by Professor Dr. Andreas Reuter, Computer Science Department. The Institute aims to investigate a broad range of questions concerning advanced computation techniques, which I will discuss briefly below. First a review of some of the work of the people associated with the institute will be given.

For the past several years a group of persons at Stuttgart has been investigating the application of parallel machines to the execution of long-lived database transactions. Long-lived transactions are those that require lengthy access to the database, such as computer-aided-design applications and office transactions, as opposed to things like debit-credit transactions. These investigations have been carried out in a project called PProcessor Organizations Supporting Parallel Execution in Complex Transactions (PROSPECT). The major goal of the project was the evaluation of possible performance improvements by massive parallelization of complex database applications. Three categories of primitives were added to the usual actions and transaction management primitives--result-oriented addressing of actions, synchronization mechanisms for cooperating actions, and dynamic allocation and scheduling of actions. One example used for testing performance of their algorithms is that of finding paths through a network of edges connecting nodes, the optimal (or shortest) path being the desired goal. Most of their work has been carried out using NonStop SQL from Tandem Computer on multiple processor Tandem machines (see, e.g., Duppel, et al., 1988a, b). The performance of the scheduler is of prime interest since it is responsible for the assignment of short tasks to the parallel processors. In tests carried out on the Tandem TCX machine with 16 processors (8 MB memory per node), it is shown that the scheduler is able to assign tasks in order to keep the processors busy, and that the throughput grows linearly with the number of processors (however, not as a multiple of the number of processors).

The Institute has a very ambitious set of objectives as outlined in Reuter (1988). Basically, the proposal calls

for a large research program involving a matrix of project areas over research groups. Each research group consists of one professor, with four research associates and secretarial support. The research groups are:

- Principles of parallel and distributed computing
- Architecture of parallel computing systems
- New technologies
- Distributed systems
- Applications of parallel and distributed systems.

Each project area within each group has two project managers. The areas are evaluation, image processing, numerical computing, and distributed systems.

Because these are long-term projects, the problem of continuity within each group is addressed emphasizing that salaries must be competitive with industry to keep key personnel for a long time. In addition, exchanging personnel among the groups gives everyone a fresh point of view.

Under the constraints of available personnel, complete realization of this project will be difficult. Reuter lists several topics that could reasonably be addressed initially.

- Fundamental research projects
  - \* Usage patterns of future very large distributed systems: Reuter envisions networks of up to 100 million computers in the near future (e.g., required by a cashless society) and this project would study the technical, legal, and social implications of such a network.
  - \* High performance numerical algorithms: Which types of numerical problems can best be mapped onto various parallel architectures?
  - \* Principles of parallel and distributed computing: The goal is to develop an abstract theory of the relations between algorithmical structures and processor structures.
  - \* New compilation and optimization techniques: Develop a theory of performance in large parallel and distributed systems to allow study of how algorithmical structures can be automatically mapped onto processor structures while meeting certain performance criteria.
- Prototype oriented projects
  - \* Performance measurement and benchmarking: Develop a suite of benchmarks and a methodology for measuring and evaluating performance of parallel and distributed systems.
  - \* Programming environments: Identify requirements for parallel programming environments; i.e., what information in which style needs to be given by the program developer

in order to enable compilers to generate efficient code for parallel computers?

- \* Generalized transaction concepts: Reuter contends that all processing in future systems will be embedded in transactions, but much more general than current systems; this project would implement and investigate prototype generalized transaction managers.
- \* Load distribution and load balancing: First, determine the parameters and constraints in load balancing by doing lots of measurements; then, evaluate some existing strategies, with the end result being a usable load balancing and load controlling mechanism for the entire campus network.
- Integrated projects
  - \* Extendible high performance architectures: This project would investigate whether there are useful architectural building blocks which make it possible to extend a given system by simply combining the base structure arbitrarily often.
  - \* Comparative analysis of application classes: This project is related to the benchmarking project above and would attempt to differentiate as well as determine which classes of applications are similar with respect to their performance on parallel systems.
  - \* Massively parallel architecture: To investigate how well apparently parallel tasks, such as neural networks and image processing, can be adapted to massively parallel machines and what the methodology looks like, and the (later) utilization of massively parallel optical devices for certain kinds of computations.

The proposal also contains plans for obtaining necessary massively parallel machines such as the Connection Machine and associated workstations and communication hardware. The university is already well equipped and has a CRAY 2 and other machines on which time can be purchased.

## Comments

Adding Höllig to the faculty at Stuttgart will help round out the emphasis on partial differential equations. The theory of box-splines is mathematically quite beautiful, and I think one can look forward to further applications. The Institute has outlined an extremely ambitious project. It will be very interesting to follow the progress of Reuter's group for the next several years.



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## Two Universities in Southern France

by Richard Franke

### Université Paul Sabatier, Toulouse, France

The Université Paul Sabatier is located on the outskirts of Toulouse, France. I visited the Laboratoire d'Analyse Numérique and the Institut National de Sciences Appliquées, where Professor Christophe Rabut was my host. Rabut works on matters related to surface approximation by spline functions, especially thin plate splines. One of the problems with thin plate spline approximation is that large systems of equations with a full matrix must be solved. The approximation does not depend on the measure of distance (or scaling of the independent variables); however, the condition number of the coefficient matrix does. Thus it is of interest to determine a scaling that is beneficial in terms of the condition number. Rabut has determined a scaling that minimizes a certain bound for the condition number of the coefficient matrix. When applied to particular sets of data, his results seem to indicate that transforming the data to roughly the unit square is the proper thing to do. Interestingly, this is in line with advice I have given in the past on the basis of my own and others' experience.

Rabut is also working on problems of quasi-interpolation and reproduction of polynomials at equally spaced nodes by quasi-interpolants. He has shown that it is possible to reproduce exactly polynomials of degree  $d = 2m - 1$  with quasi-interpolants whose basis functions are linear combinations of B-splines of degree  $d$ , and that it is possible to reproduce values of polynomials of arbitrary degree at the nodes (of course, the values cannot be matched elsewhere for polynomials of degree greater than the spline). The extension to nonequally spaced data is being attempted. He is extending the work to two-dimensional gridded data using thin plate spline basis

functions and pseudocubics. This work is related to that of Powell and his group at Cambridge (see *ESNIB* 89-05:37).

Jean-Pierre Dedieu has been working on problems related to convergence of spline and spline-like approximations. His results concern the rate of decay of the off diagonal elements of the inverse of certain block tridiagonal matrices, such as are obtained in constructing spline interpolation functions. He gives sufficient conditions for exponential decay of the off diagonal elements as the number of equally spaced points on  $[0,1]$  tends to infinity, that is, there is a  $0 < c < 1$  such that  $|a_{ij}| < ac^{|i-j|}$  (see Dedieu, 1988). According to Dedieu, the problem is also related to wavelet theory.

He is presently working on fitting data in two and more dimensions using implicit functions (polynomials) by least squares. In two dimensions, for example, the prototype problem would be fitting contour curves, given the x-y coordinates for a particular value of the function. It is possible for the curve to be disconnected (that is, to have more than one component), and this is a desirable property, since it may be the case in practice. The problem would be more difficult with parametric curves, and in addition, the parameterization is likely to be a hard problem. The problem has a free parameter, and this is taken care of by normalizing the coefficients to lie on the unit sphere in  $(n+1)(n+2)/2$  space,  $n$  being the degree of the polynomial used. The formulation of the problem is straightforward. The computation of the approximation is not easy. He has shown it can be formulated as the minimization of a quadratic functional, which then reduces the problem to that of finding the eigenvector corresponding to the smallest eigenvalue of a certain matrix.



Marc Atteia and Najib Benbourhim have recent results on what they call *elastic manifold splines*. Conventional spline theory considers scalar deformations of elastic material; e.g., thin beams, or plates. When the object being modeled is a three-dimensional manifold, the use of parametric tensor product splines (for example) does not model a similar object. Therefore, they consider the multidimensional deformation of isotropic hyperelastic material. A suitable functional to be minimized, subject to generalized interpolation conditions, is defined. A suitable space is defined and shown to be a Hilbert space and the reproducing kernel is formulated. Existence and uniqueness of the solution then follow. Details can be found in Atteia and Benbourhim (1989).

### Université de Pau, Pau, France

My visit to Pau was arranged by Dr. Peppino Terpolilli, an employee of Elf Aquitaine (Elf). He and his group work closely with some members of the Laboratoire d'Analyse Numérique at the university, in particular, Professor Remi Arcangeli and his students. Elf is a multinational company involved in oil exploration and production, distribution, and biotechnology. Terpolilli works primarily in optimization. Their principal tool for optimization is based on the trust-region techniques developed by Fletcher, Powell, Dennis, and others. These techniques solve a sequence of quadratic approximate problems, and work very well for smooth, unconstrained minimization problems. Part of Terpolilli's present work is toward development of techniques for nonsmooth and constrained problems.

My principal discussions were with the group involved in surface modeling, however, which included Terpolilli, Dr. Pascal Klein, Dr. Dominique Apprato, and Arcangeli. The problem of greatest interest is the approximation of surfaces (for example, the shape of underground strata) from scattered data measurements (subject to error, of course), but with some features that distinguish the problem here from other scattered data approximation problems. One is that the surfaces may have discontinuities in the derivative (creases), or even the surface itself (faults). Further, the surface may not be a function valued surface, but involve folds, or in the case of discontinuities, the surface(s) to be modeled may overlap. Further, the positions of the creases and faults are unknown, in general, and must be inferred from the data measurements. A blessing and a curse is that there may be many data points, perhaps as many as 10,000 or more. One approach is to assume an approximation with initial estimates of the locations of faults and creases, with an iteration to optimize on the location by minimization of some quantity such as sum of squared errors, or more usual in the French school of mathematics, a combination of terms involving a measure of smoothness of the func-

tion by a pseudonorm. One approach is through the use of *inf-convolution splines*, which were introduced by P.J. Laurent, and used to solve univariate problems concerning the approximation of functions with discontinuous derivatives by Laurent and Utreras (1986). These approximations minimize a certain pseudonorm; e.g., the thin plate functional, and consist of the usual terms plus terms that build in the faults and creases. A study of this technique was carried out by Klein (1987), a student of Laurent at Grenoble, now at Elf. The problem of overlapping, or folded surfaces (with or without a known location of the feature) is an additional difficulty. One possibility is to use a parametric form for the surface; however, the additional complication in terms of appropriate parameterization of the surface is nontrivial. Techniques used in CAGD may be of use in this context, including the possibility of using volume modeling. A better approach may be to allow overlapping of the two pieces of the faulted surface. The approach of Utreras and Laurent using the inf-convolution with generalized cross validation for detection of discontinuities may be useful in the multidimensional case. For smooth surfaces, they have used finite element approximations over rectangles, using a minimization of a combination of a smoothness term and a fidelity to data term. They also like the idea of being able to perform a local modification of the surface, which is easily constructed with this kind of approximation, although the optimality properties of the modified surface are then only approximate (Arcangeli, et al., 1985). This is probably not a serious problem, and with a suitable basis could perhaps be iteratively improved at modest computational cost.

### Conclusions

The influence of the French school of analysis is evident at these two universities, but the relationship of the Pau group with Elf brings some interesting and difficult applied problems on which to focus their work. The work at Toulouse is rather theoretical, but is potentially useful for applications as well.

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# Some Applied Mathematics and Computing at Karlsruhe University

by Richard Franke

## Introduction

I visited three departments at the Universität Karlsruhe and discussed some of the applied mathematics and scientific computing research being carried out there.

## Institute for Applied Mathematics

The Institut für Angewandte Mathematik is one of two institutes in the Mathematics Department. It is under the direction of Dr. G. Alefeld and consists of five permanent professors and eight coworkers. My contact for the visit to the institute was Dr. Andreas Frommer who recently completed his dissertation at Karlsruhe. The mathematical efforts of the institute are partly in joint collaboration with the Department of Civil Engineering, the problems being integral equations associated with such phenomena as loads on silos and computation of shocks caused by driving pilings used to support structures such as railway tracks and buildings. The purpose of the latter project is to decide how piles should be driven to control the effects on nearby structures and their contents. Since many problems eventually involve the solution of large systems of linear or nonlinear equations, certain members of the group are actively working on parallel methods for the solution of such equations. Some discussion of their efforts on these problems will be given below. In addition, the group is interested in the broad problem of attempting to derive bounds on all errors involved in approximate solution of scientific and engineering problems, so-called *safe bounds*, and consequently are working on the solution of problems within the context of interval arithmetic. The future course of their work on *reliable computation* is expected to be toward safe bounds for inverse eigenvalue problems.

Frommer and his colleague Günter Mayer are working on the computational and theoretical aspects of multisplitting methods for solution of linear and nonlinear algebraic equations. Multisplitting methods were introduced by O'Leary and White (1985) and are easily described for a system of  $n$  linear equations in  $n$  unknowns,  $Ax = b$ . In a simple splitting method,  $A = M - N$ , and the iteration  $Mx^{m+1} = Nx^m + b$  is performed. If  $M$  is the lower triangular part of  $A$ , for example, the Gauss-Seidel iteration results. In a multisplitting scheme,  $K$  different splittings,  $A = M_k - N_k$ ,  $k = 1, \dots, K$  are taken, each with an associated positive diagonal matrix  $E_k$ , with

$$\sum_{k=1}^K E_k = I, \text{ and then the iteration } x^{m+1} = \sum_{k=1}^K E_k y^{k,m},$$

where  $M_k y^{k,m} = N_k x^m + b$ ,  $k = 1, \dots, K$  is performed. The matrices  $E_k$  will generally involve mostly ones and zeros on the diagonal, the zeros corresponding to variables which (effectively) do not appear in the smaller *split* problem. Thus, the method is a device for splitting the large problem into smaller problems, or subproblems suitable for parallel computation. When all entries in the  $E_k$  matrices are zeros and ones, the method is a block iterative scheme. The communication between the subproblems is carried out by the computation of the next iterate as weighted averages of solutions of the smaller problems. The use of elements in the  $E$  matrices having values between zero and one leads to another form of communication between the subproblems, but at the expense of overlapping (hence larger, but still independent at a particular iteration) subproblems. Frommer and Mayer have investigated the convergence of such methods (1988a). The convergence is dependent on the spectral radius of the iteration matrix,

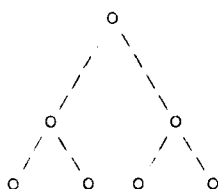
$$H = \sum_{k=1}^K E_k M_k^{-1} N_k,$$

with convergence occurring for all initial guesses if and only if the spectral radius of  $H$  is less than one. The rate of convergence is proportional to the spectral radius of  $H$ . It is of little complication to consider the SOR variant of the scheme, where the iterate  $x^{m+1}$  above is called  $z^{m+1}$ , and for a relaxation parameter  $\mu$  then take  $x^{m+1} = \mu z^{m+1} + (1-\mu)x^m$ . Frommer and Mayer proved that if  $A$  is an  $H$ -matrix (this  $H$  does not refer to the matrix  $H$  above, but the class of matrices with certain properties which often occur in applications) then certain relaxed multisplitting methods converge for any relaxation parameter in the interval  $(0, 2/(1+\sigma))$ . Here  $\sigma$  is the spectral radius of the Jacobi iteration matrix for the system  $|A|x = b$  (the matrix  $|A|$  has elements  $|a_{ij}|$ ) and is assured of satisfying  $\sigma < 1$  when  $A$  is an  $H$ -matrix. Thus, the unrelaxed iteration converges and examples show that over-relaxation yields a faster rate of convergence. It has not been shown that  $2/(1+\sigma)$  is a strict upper bound for convergence. For the special case  $K=1$ , the results reduce to relaxed Jacobi and Gauss-Seidel iterations for which the results were previously known.

The above ideas have been generalized in two ways. First, the ideas of parallel multisplitting methods have been applied to nonlinear equations (Frommer and Mayer, 1988b). Local convergence results are given in terms of an induced splitting of the linear system with coefficient matrix equal to the Jacobian matrix of the nonlinear system. Normally in multisplitting methods, the exact solutions of the subsystems are required; and since they are nonlinear, they must be solved iteratively. However, Frommer and Mayer show that it is not necessary to solve each subsystem exactly in order to preserve the rate of convergence of the multisplitting method. For example, under suitable conditions, the use of one Newton iteration for each of the subsystems results in convergence at the same rate as if the subsystems had been solved exactly. The use of nonlinear SOR methods are also considered.

The use of interval arithmetic to analyze the linear and nonlinear multisplitting methods to obtain bounds on the error in the solution of systems has been considered (Frommer and Mayer, 1988c, 1988d). In the linear system case, the problem is that of constructing the set  $\{x\}$  of all possible solutions to the systems  $Ax = b$ , where  $A \in [A]$  and  $b \in [b]$ , and  $[.]$  denotes an interval matrix; that is, the elements of the enclosed matrix (consider a vector to be an  $n \times 1$  matrix) lie within given intervals. It is assumed every such  $A$  is nonsingular. The set  $\{x\}$  is generally not an interval vector, but can be enclosed in an interval vector. Frommer and Mayer have considered this problem in the context of multisplitting algorithms, and have given an algorithm for computing the smallest  $[x]$  containing  $\{x\}$ . Knowledge of this vector gives certain bounds on the solution of the system of equations. Some examples computed on a personal computer using Pascal-SC (which allows for easy handling of interval computations) are given. For the nonlinear case, the algorithm is necessarily iterative; they investigate the rate of convergence of their method and give the results of some numerical examples.

None of the numerical results reported above have actually been carried out on a computer with parallel processors, because no parallel computer was available to them. Frommer and Mayer are now working with a company in Karlsruhe, Integrated Parallel Systems KG Wöst (or iP-Systems), that is developing a parallel computer with a novel architecture. A prototype of the machine (model TX2) with 32 processors is presently running. The machine is based on an extended tree architecture, as shown below, and with the obvious extension to an arbitrary number of levels (each  $\circ$  represents a processor):



The generalization to more than seven processors is obvious. Some features of the architecture are:

- Extension to more processors maintains the same pattern
- Because of the builtin divide-and-conquer strategy embodied in the architecture, no changes to programs need to be made when running on a machine with a different number of processors
- Communication is along the given lines and must be initiated by intermediate nodes, but data does not *pass through* an intermediate node, so they are only momentarily interrupted by data passing
- The upper nodes of the tree are primarily used to divide the computations among the *leaf* nodes and are thus mainly involved in communication. Because of this, the upper nodes (along with the required one additional node) are mapped to be leaf nodes as well
- Each node of the TX3 (with floating point unit) is capable of 40 MFLOPS, peak performance (the company will give only sustained performance figures)
- Models with 512 up to 4096 processors are envisioned
- Each node has memory of 4 MB, for up to 16-GB total memory
- A programming construct called a *wave* initiates the distribution of tasks among the processors and is then carried out by the hardware.

Several applications have been implemented on the prototype system for demonstration purposes, including SOR solution of the finite difference approximation to the Poisson equation on a rectangle, the exact solution of the traveling salesman problem with nonEuclidean (and non-symmetric) distances, and Monte-Carlo simulations of the nearest neighbor Ising model for ferromagnetism (Block, 1989; Ferstl and Thurner, 1989; and Strittmatter, 1989, respectively).

## Computer Center

I spoke with Dr. Willi Schönauer at the Rechenzentrum der Universität Karlsruhe. Schönauer's training is in mechanical engineering and his research activities are influenced by the computational facilities. The computer center at Karlsruhe University recently acquired a Siemens VP400 supercomputer, replacing the existing Cyber 205. The new computer is a model made by Fujitsu and marketed in Germany by Siemens. Amdahl markets the same machine in the U.S. The machine has 4 vector pipes giving it a peak computation rate of 1.7 GFLOPS. Schönauer is a very strong advocate of the use of vector supercomputers for a mix of scientific problems such as occur in universities or in companies that manufacture items such as cars or airplanes. Schönauer has attempted to

spread widely his message concerning "why I like vector computers" (see Schönauer, 1989, for the latest version; the first is a chapter in his book, Schönauer, 1987). He does not think it is likely that massively parallel machines will be able to achieve the same level of throughput as multiple pipe vector processors over a mix of applications. He feels the type of programmer care that must be taken with vector computers; e.g., to form long vectors in the innermost loops, is more natural than chopping a problem into smaller pieces for distribution to parallel processors, then recombining as necessary for the final results. While he strongly advocates the multiple pipe vector approach for multipurpose scientific computing, he also advocates research into the use of massively parallel machines to determine the special niches into which he feels such machines will be able to perform more efficiently than vector supercomputers. In his opinion, it is necessary for the hardware and support software to be able to partition the problem among the parallel processors without programmer intervention.

The work of Schönauer and his colleagues is in the application of supercomputers to the solution of partial differential equations. The long term goal is a *black box* solver that takes as input the system of equations with boundary conditions and then returns the approximate solution, reliably accurate to a specified tolerance. A program, FIDISOL, is available for the solution of nonlinear elliptic and parabolic equations in two and three dimensions (see Schönauer and Wietschorke, 1987 and Schönauer, undated). Adaptive finite difference methods are used; the domain is restricted to be a rectangle (cube) or one that is logically equivalent to it through a nonsingular transformation. One avenue of further research is toward increasing the flexibility of the finite difference method, and toward better iterative schemes for solution of the equations. To the latter end, experiments are being conducted on multilevel schemes for solution of linear systems. Finite element methods have an easy local refinement of the mesh; however, the structure of the resulting system of equations is not so readily amenable to vectorized methods for solution because of the relative lack of regularity in the nonzero matrix entries, compared with finite difference methods. The commonly used data structures for storing the matrices result in a time-consuming process for building long vectors. A second avenue for research is to find new data structures for storing finite element method matrices that are amenable to easy vectorized method for the solution of the equations. A program that can use various types of elements, uses a data flow algorithm, and is claimed to vectorize very well has been written and tested (see Sternecker and Schönauer, 1988).

## Geodetic Institute

Mr. Roland Klees was my host at the Geodätisches Institut where I spoke with him about his work in attempting to solve the oblique derivative fixed boundary value problem of physical geodesy. The problem is to determine the potential of the earth in outer space by assuming that the boundary surface is known and the magnitude of the gradient of the earth potential is known at some points of the boundary surface. The equation to be solved is Laplace's equation in the region outside the earth. While the magnitude of the gradient is known at some points, and the surface of the earth is known, the direction of the gradient (which is not normal to the surface of the earth), is unknown. Because of this, the problem to be solved is nonlinear. The problem is linearized by using the direction from a reference potential field to approximate the true direction. The problem is converted to an integral equation form, a singular integral equation of the second kind. The integral exists only in the sense of the Cauchy principal value. This equation is to be solved using a boundary element method. Because the gravity field is only known at scattered points, it is necessary to interpolate this data in order to evaluate the integrals. The problem will be solved only over a small portion of the earth. The main problems are that

- There is a huge amount of data; e.g., the surface of the earth is defined from a digital terrain model with point distances of about 50 meters, with associated boundary values (gravity and reference gravity data)
- The coefficients of the system of equations involve the evaluation of integrals in two and four dimensions, the inner double integral of the four-dimensional integral existing only in the Cauchy principal value sense. The other integrals may be weakly singular
- The system of equations will involve up to 10,000 unknowns.

Further information on the problem can be found in Heck.

## Summary

There is much interesting work being done at Karlsruhe University. The general area of reliable computation and safe error bounds is one that is likely to receive much more attention since it is becoming computationally feasible for many problems because of widespread availability of supercomputers. Parallel computing systems are becoming more widely available for use on problems for which they are suited, and some nice work is being done on parallel algorithms for solution of linear systems. Applications on the iP-Systems TX3 will help

demonstrate possible advantages of the architecture of the machine and will be followed with interest.

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# Numerical Analysis and Computing in Northern Italy

by Richard Franke

## University of Bologna

The host for my visit at Bologna was Professor Ilio Galligani. The University of Bologna, the oldest still-existing university in the Western world, is a large university situated near central Bologna. Since there is no tuition and no entrance exam (an exception is computer science, which chooses the top 120 students per year through an exam) perhaps one half of the 50,000 students are serious. While the exact age is not known, what they labeled as the 100th anniversary of their 800th anniversary was held in 1988. For some hundreds of years, it did not exist in the formal sense of having a campus and faculty, but rather in the sense that *professors* took on one or more students on a somewhat formal (paying) basis. This continued until the time buildings and the modern trappings of a university were constructed within the last several hundred years. What has been lost in the following period is that the students no longer pay directly for their education; however, this is not all bad.

The facilities for mathematics and computer science seem to be excellent. There are about 60 mathematics majors and 120 computer science majors per year. The computational laboratories seem to have an ample number of machines available, of an almost bewildering variety, including PC's and PC clones, Apple II's, and Macintoshes. In addition, there is a laboratory with Sun

workstations, and connections to the mainframe computers at the computer center.

## Project on Parallel Computing

Until personal problems intervened, Galligani was the head of the Italian National Research Council (CNR) (Consiglio Nazionale delle Ricerche) project in *information systems and parallel computing*. Funds of 13 billion lire (about \$10 million) are provided per year for a 4 to 5 year project. About 30 percent supports parallel computing research, with perhaps a similar amount for parallel computing coming from CNR funds for other research that incidentally uses parallel computing. The primary focus of the research programs is toward computers with a few fast vector processors, perhaps because the existing facilities (see following discussion about the computer center) embody this type of machine. There is no hypercube computer in any university in Italy.

Professor Renato Capocelli, University of Rome, is the present head of the project. The impetus for supercomputing in Italy has come mainly from the applications oriented researchers, with only limited interest in the project from *pure* numerical analysts. Some 6 years ago, the initial impetus for obtaining a supercomputer came from several applications-oriented research groups when the computer center had only an ancient CDC 6600. I spoke

with Galligani about some of the projects in the parallel computing effort and will describe them later. Generally, the effort is not all at one facility.

**Computational Physics.** Professor Reatto, University of Milan, leads this group, although much of the work is being done in Trieste. They are interested mainly in the structure of matter, rather than particle physics, and the typical computational problems they are interested in solving are very large nonsymmetric matrix eigenvalue problems. The entries in the (nonsparse) matrices are integrals in six dimensions, which can themselves be time-consuming to evaluate since this must be carried out to high precision.

**Chemistry.** Professor Paluieri, University of Bologna, heads this group, but the effort is concentrated at the University of Pisa and CNR centers in Pisa. This work is geared toward modeling matter from a chemistry point of view, again oriented toward its structure. The problems tend to large nonsymmetric eigenvalue problems, similar to those of the physics group.

**Astrometry.** Data for the problem to be solved have not yet been obtained. The aim is to construct star catalogs using data obtained by the European Space Agency satellite telescope, Hipparcos. From the data obtained by Hipparcos, two star catalogs will be constructed. One catalog will have positions, parallaxes, and proper motions of 100,000 selected stars, with positions and parallaxes expected to be accurate to 0.002 arcsec--about 20 times better than is possible with earth based systems--and proper motions to about 0.002 arcsec/year. The second catalog will have positions of 400,000 stars to somewhat less accuracy. The star positions will be computed by least square approximations using different observations. This least squares problem involves about 200,000 unknowns and 1,200,000 equations. Simulations with up to 40,000 stars have been conducted with excellent results (see Galligani, et al., 1986). The basic computational method is that of Paige and Saunders (1982) that uses the Lanczos method to solve sparse overdetermined linear systems.

**Mesoscale Weather Prediction.** A group in Bologna and University of Modena under Prof. Navarra of Modena is attempting to predict weather locally in the Mediterranean area using as boundary conditions the predictions of the global model run by the European Center for Medium Range Weather Forecasting in Reading, U.K. The ECMWF uses a spectral model, as will the group in Italy. A large portion of the computation involves solving large sparse nonsymmetric systems of equations, so one of their interests is in methods for efficiently solving such systems of equations.

**Numerical Solution of Partial Differential Equations.** Much of this work is taking place at the University of Pavia, and is discussed in some detail later in this report.

## CINECA, the computing center

The Consorzio Interuniversitario Nord Est Calcolo Automatico (CINECA) was formed by a consortium of universities in northeastern Italy to provide large-scale computing services. There are two other similar centers in Italy--the Consorzio Interuniversitario Lombardo per la Elaborazione Automatica in Milan, northern Italy, and the Centro Studi ed Applicazioni in Tecnologie Avanzate in Bari, southern Italy. While the primary purpose of the center is to provide educational and research computing support, time is also sold commercially to companies such as FIAT, which amounts to about 30 percent of the central processing unit time. The CINECA has a staff of about 70 to provide instruction and support services as well as to perform the administration of the center. The main machines at the center consist of a Cray XMP/12 (the first machine that was obtained before the conception of the parallel processing initiative), a Cray XMP/48, and an IBM 3090/200 with vector facility. The computing facilities for the project on parallel computing were obtained by CINECA with help from CNR and the Italian Ministry of Public Education. The Ministry recognized that advanced scientific computing facilities could be used for educational purposes as well as scientific purposes, which leads to new technical jobs. Consequently, the facilities are made available for research and educational purposes for a nominal charge.

## Numerical Analysis at University of Bologna

Galligani is involved in several projects in addition to that mentioned above. One ongoing project is an investigation into the arithmetic mean method for solution of systems of ordinary differential equations on a multiple processor computer. Consider the initial value system

$$v'(t) + Av(t) = b, v(0) = g,$$

where  $A$  is an  $n \times n$  constant matrix and  $b$  a constant  $n$ -vector.  $A$  is assumed to be large and sparse (but not a random sparsity pattern). Typically the system can be thought of as arising from the method of lines for solving a partial differential equation. The arithmetic mean method is an explicit alternative to the alternating direction implicit method, wherein a step of the solution is obtained by taking two steps, each corresponding to a splitting of the matrix  $A$  into different directions, with the final result being the average of the two. The method is shown to be consistent, of order two, and stable for all stepizes if  $A$  is symmetric positive definite, and also under somewhat weaker conditions (Galligani and Ruggiero, 1988). The interesting aspect of the method is that the two steps can be computed in parallel, thus resulting in near linear speedups on a computer with a small number of processors and shared memory (in this case, two processors on the Cray XMP/48), with typical speedup ratios

of 1.9 over a range of problem sizes. The scheme has also been investigated for nonsymmetric  $A$  (Galligani and Ruggiero, 1989a) and essentially positive  $A$  (Galligani and Ruggiero, 1989b). The analogy with ADI suggests the method may be usefully adapted to solving large linear systems of algebraic equations arising from elliptic problems as well, and the scheme has been compared with the biconjugate gradient method of Fletcher (1975). It was found (Ruggiero and Galligani, 1989) that the number of iterations required was much greater when the coefficient matrix was symmetric, but that for very non-symmetric problems the situation was reversed.

L. Montefusco and G. Casciola (1989) have published an algorithm for interpolation of scattered data in the plane based on a triangulation of the  $x$ - $y$  data, with estimates of partial derivatives at the vertices obtained by minimizing a pseudonorm involving a tension parameter for a network of curves over the edges in the triangulation. The work is somewhat similar to that of Nielson and this writer (1984), except that the network of curves is assumed to be cubic. While this seems somewhat curious as the natural solution to the minimization problem is exponential rather than cubic, the resulting algorithm is simpler, and examples show that the tension parameters can be used to control the surface in the vicinity of large gradients, where overshoot of the surface frequently occurs. In addition, the evaluation process for the surface is simplified since on each triangle the surface is a nine parameter patch with cubic boundary curves.

Another activity in the department is image processing, both that oriented toward medical imaging such as computerized tomography, and restoration of images degraded by noise. The work here has in part been into the efficiency of algorithms on a vector computer such as the Cray XMP/48 (Guerrini and Spaletta, 1988, and Guerrini, 1988). Additionally, they have developed an interactive system for enhancement of colposcopic images taken by video camera-densitometer, together with the Institute of Obstetrics and Gynecology II at the University of Bologna (Guerrini, et al., 1988). The software was written in Fortran 77 and runs on a Tower 1632 NCR computer, with a Tektronix 4105 color graphics terminal for the imaging. In addition to image enhancement, the system can reconstruct undefined zones and perform morphological analysis and measurements of atypical colposcopic areas. Several different processing methods can be chosen from to detect boundaries and point out areas of biological interest.

## University of Florence

My host at the University of Florence was Professor Ferruccio Fontanella of the Department of Energetics. The University of Florence has some 40,000 students and is spread out over northern Florence. As is typical with

Italian universities, not all are serious students. About 120 students begin the mathematics program per year, with perhaps one-half finishing the first degree (Laurea) sometime later (nominally four years). The undergraduate education in Italy is fundamentally different from that in the U.S. in that the student takes almost no courses geared toward a general education, and a graduate mathematics major will have taken almost exclusively technical courses such as physics and chemistry besides the mathematics. All general education is carried out at what is comparable to the high school level. On the other hand, few students will have taken Calculus at the high school level in Italy. A thesis is required for the Laurea, making the degree somewhat closer to our Master's degree than the Bachelor's, and the Ph.D. degree generally takes an additional four years. Before a student can enter the program, he must pass a competitive test for fixed vacancies. Several smaller schools feed their graduates into the University of Florence. It would be unusual for a graduate of University of Florence to attend another university for the Ph.D. degree. Although students generally do not move to different schools for advanced degrees, the candidate must pass a final examination before a national committee. In a sense, this is quality control that in the U.S. is served by the usual (but not uniformly observed) practice of students attending different schools for advanced degrees, but where there is no equivalent enforced outside inspection of the product.

**Research in the Departments of Energetics and of Mathematics.** Fontanella has been involved in approximation theory and he and his students have published papers in this area. Because the interests of his department are oriented toward engineering, he is reorienting his research direction more toward the mainstream interests of the mathematicians in his department, which is predominantly numerical solutions of partial differential equations. One area of interest is in copper casting (see Del Puglia, et al., 1987). I spoke with two of his approximation theory students--one current and one former.

Carla Manni is pursuing the Ph.D. degree under the direction of Fontanella. She is studying the problem of the dimension of spaces of piecewise polynomials over polygonally subdivided domains. This is a difficult problem, even in the case of triangulated domains, since the dimension depends not only on the topology of the space, but also the geometry. For example, the dimension of  $C^1$  piecewise quartics over a convex quadrilateral region subdivided into 4 triangles by specifying a point in the interior which is then connected to the vertices, depends on whether or not the interior point is the intersection of the diagonals of the quadrilateral. There is a large literature on the topic, many of the results being associated with the names C. K. Chui, P. Alfeld, L. Schumaker and their coauthors (see Alfeld and Schumaker, 1987 for the flavor of some results). The potential importance of these mat-



ters is in applications such as finite element problems, where essentially the same fitting power could be obtained with fewer unknowns than with completely local bases such as are used now. However, the sparseness structure of the coefficient matrices would be adversely affected.

Typical results are usually in terms of upper or lower bounds for the dimension. Because of the nature of the problem, specific results for simple cases involving some generality are publishable results. Manni is pursuing the idea of cross-cut lines (polygonal boundaries that make a straight line to entirely separate the region) and their influence on the dimension of the space for polygonal (not necessarily triangulated) domains. In the case of the smoothness of the space of piecewise polynomials being small in relation to the degree of the polynomials (for triangulated domains the inequality  $d \geq 4r + 1$ , where  $d$  is the degree and  $r$  is the smoothness, is important), she hopes to be able to make some progress.

Professor P. Constantini is at the University of Siena and, along with Manni, is working on shape preserving interpolation schemes. The problem they are presently attempting to solve is that of bivariate monotone interpolation where the Hermite data (values, first partial derivatives, and cross partial derivative) are given on a rectangular grid, and are consistent with a function that is monotone in the coordinate directions. Past approaches to the problem have assumed only function values given, and either relied on a global process for construction of consistent derivatives, with the resulting function being piecewise cubic on the rectangular mesh (Carlson and Fritsch, 1985 and 1989), or with more freedom in choosing derivatives, but each rectangle being itself subdivided for the piecewise polynomial approximation (Beatson and Ziegler, 1985, or Asaturyan and Unsworth, 1988). Here the approach they want to take is that of increasing the degree of the polynomial to preserve the shape of (first) the network of boundary curves over the grid. They do this by using the Bernstein-Bezier net for constructing the approximation, where the derivatives will dictate the first interior control point, and the remaining part of the control polygon will join these two points with a straight line. Because, as the degree is increased, the control polygon (and hence the approximation) approaches a straight line, some degree of approximation will result in the monotonicity being preserved. They are able to construct the network of boundary curves with local dependence, the curves depending only on data within one rectangle and the four adjoining ones to the left, right, above, and below. The surface will then be defined using the same ideas for a blending method over each rectangle.

The group led by Antonio Fasano and Mario Primicerio in the Mathematics Department has strong ties with the European Consortium for Mathematics in Industry

(see ESNIB 89-01:28) and many of their research interests are associated with industrial problems. Fasano directs the Florence component of a CNR project on Industrial and Technological Applications to Mathematics in Industry, as well. They have a group effort consisting of about six faculty and students at various stages of their studies, totaling about ten persons at any given time. I will briefly describe some of their activities to give the flavor of their interests.

**Continuous Metals Casting.** One problem considered here is cooling process control by altering the pressure of the cooling water to approximate a prescribed solidification front as closely as possible. This is an inverse Stefan problem.

**Coal-Water Slurries.** It is desired to move coal through pipelines as a slurry consisting of up to 70 percent coal that can then be burned directly without first removing the water. The coal is coated with a chemical so it does not absorb water which then will be available as a lubricant. This mixture is statically stable over many years. In test facilities it was discovered that, after some period of time, the viscosity of the mixture began to increase, and eventually became too viscous to pump. The goal of the study was to try to identify the factors that caused this to occur, and to be able to predict, on the basis of type of coal, the components of the mixture, and the pumping parameters, when the increase in viscosity would occur and how rapidly it would increase. The results are described in Primicerio (1988).

**Bimetallic Strip Fabrication.** The source of this problem is the bearing industry that wants to make (slip) bearings with steel substrate and a bronze wearing surface. This is done by heating a continuous strip of steel to above the melting temperature of bronze. A bronze film is obtained by solidifying bronze on the strip by cooling the strip with an oil shower. The shape of the bronze film should be determined in terms of the parameters of the problem. This is modeled as a parabolic free boundary problem that is solved numerically.

**Crystalline Structure of Polymers.** According to the group, studies in the past have generally concentrated on the macroscopic view, the determination of things such as the percent of a certain crystalline structure obtained. For some critical components, such as artificial human joints, they want to know more details about the structure, since the mechanical behavior depends on it. In particular, the group wants to learn more about the dimension of and the number of crystals. The dynamics of the formation of the crystals is somewhat similar to population dynamics, being described mathematically by an integro-differential equation with growth and *death* terms as well as terms having a global dependence. The problem is easily treated mathematically for existence and uniqueness of solution. The numerical simulation of the time history of the formation will initially ignore the latent heat of crys-



tallization. The application of high pressures (perhaps up to 1,000 atmospheres) alters the way the process proceeds, and eventually they hope to model this as well. The U.S. Army has funded previous work in polymers (see Fasano, et al., 1986), as well as work on ground-freezing processes (Fasano and Primicerio, 1988). Other work on Stefan problems has been joint work with Howison and Ockendon at Oxford University, and has had ONR support (see Fasano, et al., 1989).

Fasano is very active in the Italian mathematical community, besides the industrial activities mentioned above. He was instrumental in establishing the Society Italian for Mathematics Applied and Industrial (SIMAI), which seemed necessary since there previously was no such national group to serve as a contact for Italian mathematicians with the International Conference on Industrial and Applied Mathematics (ICIAM, sponsored jointly by the German, British, U.S., and French mathematics organizations--GAMM, IMA, SIAM, and SMAI; the first meeting was in Paris in 1987, the second will be in Washington, DC, in 1991). Fasano serves as the general coordinator of a large project (about 100 mathematicians at 12 universities) on evolution equations for which the Italian Ministry of Education provides funds.

### University of Pavia and the Numerical Analysis Institute

The University of Pavia is located in the small town of Pavia, just southwest of Milan. The university is small by Italian standards--about 22,000 students. My host at Pavia was Professor Enrico Magenes, who is the head of a CNR institute, the Istituto di Analisi Numerica. The institute and the university coexist and share personnel, housed in a fourteenth century building in Pavia. Happily, it has been updated on occasion (although not often enough), and in the next few years they will move to the site already occupied by the engineering school.

**Areas of Research at Pavia.** About 30 persons at the University of Pavia and at the Numerical Analysis Institute are interested in a variety of applied mathematics and numerical analysis problems. In addition, there are others at the university interested in pure mathematics. With 30 active researchers, it is not surprising that they have a large number of interests. These areas and persons working in them are

- Semiconductor modeling-F. Brezzi
- Free boundary problems and fluid flow through porous media-C. Baiocchi, G. Galardi
- Free boundary problems in change of phase-E. Magenes, A. Visintin, C. Verdi
- Theoretical linear and nonlinear elasticity-F. Tomarelli, C. Baiocchi, F. Gastaldi, G. Gilardi

- Biomathematics: Modeling of the propagation of the electrical field generated by the heart-P. Colli-Franzone, L. Guerra
- Biomathematics: Models of muscle contraction-V. Comincioli, A. Torelli
- Finite element methods-F. Brezzi
- Spectral methods and applications to fluid dynamics-F. Brezzi, A. Quarteroni, C. Canuto
- Fluid dynamics: Euler and Navier-Stokes equations-F. Brezzi, A. Russo, A. Quarteroni.

From 1986 to the present, the publication list includes more than 160 entries (refereed publications, papers submitted, conference papers). I spoke with some of these people about their work and the information is summarized below.

**Semiconductor Modeling.** F. Brezzi is internationally very well known in the finite element field and has collaborated with U.S. workers in the field. He feels his work in semiconductor modeling has, somewhat surprisingly, not been motivated by contacts with industry. Although the group is in contact with people in industry, he feels their work is at a very simple level compared with the problems the industry wants to solve. The semiconductor equations for a single device in steady state are simple, but nonlinear, consisting of a diffusion type equation, with equations for conservation of current considered to be of supreme importance. The numerical equations require a certain amount of attention to detail in order to proceed efficiently. The obvious iterative method is not satisfactory; and Newton's method, while very efficient for a suitable initial guess, fails without a proper initial guess. A parameter  $\epsilon$  (a kind of diffusion coefficient) usually has a rather small value, but for large values the equation is easier to solve. Therefore a continuation method in  $\epsilon$  is used, letting  $\epsilon$  decrease to the value of interest. As it turns out, the semiconductor industry is also interested in a sequence of solutions, not in terms of  $\epsilon$ , but in terms of the impressed voltage,  $\alpha$ . The reason is that the current leaps to a second branch of the solution curve if  $\alpha$  is too large. Their interest, then, is in solving the equation by continuation in terms of  $\alpha$ . The continuation in  $\epsilon$  turns out to be more natural in the sense that certain properties of the solution are only changed slightly by changes in  $\epsilon$ , while continuation in  $\alpha$  does not result in small changes. One of the problems being considered is a method where both variables vary in such a way the nice properties of continuation in  $\epsilon$  are preserved, while in the end only  $\alpha$  is changed. Other investigations are into the similarity with fluid dynamics, equations, and interpretations of the numerical methods in terms of being an *upwind* scheme (see Brezzi, et al. 1988).

**Change of Phase Problems.** The Pavia group is working on adaptive finite element methods to solve change of phase problems. They work with the entropy equations;

the finite element formulation of the problem uses linear triangular elements and, while nonlinear, is shown to have a unique solution. A nonlinear version of SOR is used to solve the equations. The adaptive algorithm they have derived (and for which they have convergence proofs as the mesh size goes to zero) has the following features:

- The mesh is almost completely redefined when changed, and in particular, the new mesh is not a refinement of the old mesh. Values on the new mesh are obtained by interpolation from the old.
- Since entropy jumps at the phase boundary, they avoid interpolation to a new mesh from the old in this region by always keeping any triangle in which the phase changes.
- All free boundaries must remain in the refined region between remeshing steps.
- There is a target number of timesteps between remeshing, and the area required to have a fine mesh is estimated by looking at the one-dimensional velocity for the problem. However, if the phase boundary reaches certain marked triangles before that many steps, the remesh must be carried out. However, it is important to not carry out the remeshing process too often.
- The new mesh is determined in part by attempting to equidistribute interpolation errors over the mesh; i.e., the size of the triangles is based on the second derivatives of the solution. In addition, a suitable aspect ratio of the triangles is maintained (Paolini and Verdi, 1988).

With the above considerations, they are able to prove that the algorithm is stable and convergent. In practice, it also requires less computation for given accuracy than is required by a uniform mesh (Nochetto, et al., 1989).

The group wants to consider the following types of problems:

- Problems where a free boundary pops into the region
- Problems that have regions where the two phases coexist
- Problems where free boundaries come together; e.g., the melting dog bone problem.

### Institute for Applied Mathematics, Genoa

While at Pavia, I talked to Enrico Puppo about his work at the Istituto per la Matematica Applicata-CNR in Genova. He and Leila de Floriani are working on surface representation schemes over triangulations (and higher dimensional analogs), usually by piecewise linear functions. Some of the applications in which they are interested are terrain representation and associated problems such as computation of what part of the surface is visible from a given point. For this application, they must be able to handle triangulations subject to several conditions.

First, they ordinarily want to have an *optimum* triangulation of a set of points (I'll mostly discuss only the planar case), in the sense of the Delaunay triangulation, which has a nice duality with the Dirichlet tessellation (also known as the Veronoi diagram) of the set of points (Lawson, 1977). The important property is that it has, over all triangulations, the largest possible minimum angle. Further, there are nice algorithms for computing the Delaunay triangulation by local swaps of diagonals of convex quadrilaterals made up of two adjacent triangles with a common boundary, a property not necessarily enjoyed by other *optimal* criteria (Schumaker, 1987). The above is all rather straightforward and well understood. The interesting problems being addressed by De Floriani and Puppo had to do with inserting and perhaps deleting points (needed for adaptive refinement of the surface), and the desire to preserve certain constraints on edges that must appear in the triangulation in order to preserve ridges and valleys of the approximated surface. Such triangulations are called *constrained Delaunay triangulations* if they otherwise satisfy the max-min angle criterion. The analog with the constrained Dirichlet tessellation is less clear. (See De Floriani, et al. [1988]; De Floriani and Puppo [1988a, and 1988b]; and De Floriani [1988]).

### Sacred Heart Catholic University, Brescia

Alfio Quarteroni is Professor and Chairman of the Mathematics Department at Università Cattolica del Sacro Cuore. He is closely associated with the group at Pavia, having obtained his "Dottore" degree there in 1975 and spends one day per week in Pavia. In addition to his work with the group at Pavia, he also works with a group of his previous students, mainly scattered around northern Italy, and some other people at the University of Trento. Their work is generally in numerical methods for fluid dynamics, both viscous and inviscid compressible flows, and incompressible flows, but also concerns the Korteweg-deVries equation and basic methods for elliptic partial differential equations. Their approaches include finite element and spectral methods and the use of domain decomposition (see Funaro, et al., 1988), including some attention to parallel processing issues.

The principal problem on which Quarteroni is currently working, along with F. Gastaldi and G. Sacchi-Landriani of Pavia, and L. Gastaldi of Trento, is the problem of solving for the flow around a body such as the European Space Agency HERMES shuttle. Their work is partially funded by ESA, with additional funding from CNR and the Ministry for Education. Near the body, the flow is viscous and is properly modeled using the Navier-Stokes equations, with a high accuracy method such as a spectral scheme used to approximate the solution. Far from the body, the inviscid Euler equations suffice, with a robust low-order scheme such as finite elements used

for the solution. Use of only one of the equations for the entire domain of interest either requires too much effort to solve the Navier-Stokes equations to obtain the near-body solution to sufficient accuracy to capture the details of the flow, or sacrifices the near-body solution in using the Euler equations.

Quarteroni and his group propose to use a hybrid approach to solve for the entire flow field in an efficient manner. In the near-body domain, the Navier-Stokes equations will be used with a spectral method for solution, while in the far-away domain the Euler equation will be solved using a finite element method. Some attempts at performing this kind of calculation in an iterative fashion have been attempted in the past, but the manner in which the coupling together of the two methods/domains has been carried out is questionable. Quarteroni feels that it is presently an open problem as to how the matching must be performed. That is, what variables must be matched, and how to do this between two different equations for which two different solution schemes are used.

They have investigated the problem of determining what variables must be matched at the interface, and which must not be, in order to be consistent. A preliminary investigation of the one-dimensional case was reported on in Quarteroni and Gastaldi (1988). Unfortunately, these results do not immediately generalize to higher dimensions. The results of further work are reported in Gastaldi, et al. (1989). Here they have reported on some numerical experiments based on their work in coupling together hyperbolic and parabolic equations across a common boundary in two dimensions.

Remaining work is that of demonstrating that the method works and is efficient. The scheme will be carried out in an iterative way; beginning with the solution of the near body equations, computation of interface conditions, followed by solution of the far-body equations, resulting in new boundary conditions for the near body equations. The solution techniques for each of the domains may be carried out on a computer with parallel processors.

## Conclusion

The parallel computation project in Italy suffers from the lack of availability of massively parallel machines. Because of this, most work is of a theoretical nature or is concentrated on machines such as a CRAY with only a few processors. Some of the work carried out in Bologna has consisted of the necessary process of trying out various algorithms to see how, or whether, they work compared to others. The connections with industry at Florence seem to yield some very interesting and challenging problems, as well as giving a more applied appearance to the education of students. The work at Pavia

(and Brescia) on numerical solutions of partial differential equations is quite extensive and, especially for the coupling of different equations, seems to be at the forefront of the art.

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## Universitat Politècnica de Catalunya, Barcelona, Spain

by Richard Franke

### Introduction

The Polytechnical University of Catalonia (UPC) is located in Barcelona, Spain. Professor Pere Brunet, the Vice President for Research and Professor of Computer Science, arranged for my visit. While there, I visited two groups--the Computer Science Department and the School of Civil Engineering. I will briefly describe some of the activities of Brunet's group, but concentrate mostly on robotics, computer architecture, and scientific computing for civil engineering applications.

### Department of Computer Science

There are about 2,500 students in computer science. Research activities are in electronics, analog and hybrid design, digital circuits, Very Large Scale Integration (VLSI) design, peripheral devices, computer design, computer aided manufacturing, and robotics. Each of these projects is being carried out in collaboration with industry and other universities and research facilities, both in Spain and elsewhere in Europe.

**Solid Modeling.** Brunet and his group work in various activities related to solid modeling, including three-dimensional (3-D) rendering, solid modeling through boundary representations, extended octree models and Constructive Solid Geometry (CSG) and free form surface design. As part of this work, a solid modeler Depart-

tament de Metodes Informatics ("DMI") has been designed and implemented (see reference). An extended octree representation is used. Solids can be generated in various ways, including parallel, circular, and conical sweeps. Arcs and circles are represented approximately to the precision specified by the user. A full complement of operations on the objects is available, along with various visualization techniques, including wire-frame, hidden line elimination, simulated lighting, and Gouraud shading.

**Robotics Research.** The Department of Computer Science has about nine members engaged in research activities in robotics. I discussed some projects in computer vision with Professors Josep Amat and Alicia Casals.

SKIDS is an acronym for Signal and Knowledge Integration with Decisional control for multisensory System, which is supported under European Strategic Program for Research and Development in Information Technologies (ESPRIT-I) between 1987 and 1990. The goal of the project is to provide basic concepts for the integration of sensory information and knowledge into systems for the recognition of certain objects through edge detection in scenes obtained by a video camera. The simplest of these systems just detects edges in a scene and presents those on the monitor. More sophisticated versions seek out particular types of edges. I saw a video demonstration in which the system was given a particular shape

which was to be extracted from a moving video image and tagged by a circle (or other symbol). In some cases the shape was input, while in others the system learned the shape by having the feature *targeted* in a scene. Features that were tracked included those such as a bird flying (a hawk), a person walking, a motorcyclist traveling on the street, the double line in the center of a street while the video was taken from a moving vehicle, a mountain peak that was tracked while the camera was panned and zoomed, and electronic parts such as transistors on a moving belt. The algorithms used are based on Hough transformations (see Martinez and Llario [1988] and Amat and Casals [1988]).

The goal is to provide the hardware and software for such systems. The use of VLSI to implement in hardware the detection of a smaller region in which the object to be located exists is the ultimate goal. The smaller scene is then processed using algorithms implemented in software. An important aspect is that the system must operate in real time.

The project Intelligent Process Control by means of Expert Systems (IPCES) is supported by ESPRIT-II between 1989 and 1992. In this project, the goal is again to design VLSI hardware to implement vision systems for automatic control of industrial processes. One possible application is in quality control, where an expert system is to automatically detect anomalies in a product and subsequently initiate corrective action without the necessity of stopping the production line. Video demonstrations showed that the system could detect electronic parts with defective connectors. Thus, such a system could alert the expert system about the defect (say, one in a catalog of possible defects), which could then (ideally) initiate action to correct the problem. The final objective of this project is to implement a prototype system in a real manufacturing industry environment to test the performance of different modules and to permit an evaluation of practical results.

A third project is on autofarming systems and is supported by the European Research Coordination Agency (EUREKA) program between 1989 and 1991. The objective of this project is to equip farm machinery with computer control equipment to enable automatic adjustment of the equipment to enable efficient cultivation and harvesting of crops. In some instances, it may be possible to completely automate the driving and steering of the machine as well.

Another interesting application was an extension of menu picking via a mouse which is usable by handicapped persons. In this case, a video camera tracks the eyes and nose of a computer user; the user's head movements then control the position of a cursor on the monitor. Various functions can be selected by positioning the cursor. Based on the last position of the cursor (on a menu item) the question of whether this function is actually desired is

indicated when the user moves the cursor to a "yes" or "no" position on the menu. (see Amat, et al., 1987).

**Computer Architecture Research.** The computer architecture group at UPC consists of about 40 professors. I spoke with Professor Mateo Valero about their work. The group is interested in looking at algorithms for five different architectures: systolic arrays, Multiple Input Multiple Data (MIMD) machines with shared, or with local memory, and vector computers with a single processor, or with several processors and shared memory. The algorithms of interest to them include the BLAS 1, 2, and 3 (less interest for the vector machines, since they are well studied elsewhere, than for the other machines), solution of linear equations using direct (LU and QR decompositions) and iterative (Gauss-Seidel, Jacobi, and conjugate gradient) methods. The interest in solution of equations is driven by applications in the solution of partial differential equations, especially nuclear power plant simulations, and the problem of radar reflections from aircraft. One of the goals concerning the radar reflection problem is to adapt an existing sequential Fortran algorithm based on a finite element method to systolic arrays and the MIMD machines. The nuclear power plant simulation problem involves similar goals. The existing algorithm embodied in RELAP5, version 2, is to be implemented on the systolic arrays and the MIMD machines. Another problem of interest is the computation of molecular dynamics, both the short range (Lennard-Jones method) and long range (Ewald method) problems. The group hopes to carry out some of the work on a machine obtained under the SUPERNODE project, for which funding is being sought from the EEC. The machine itself consists of nodes that have 16 Transputers connected through a CROSSBAR network (CROSSBAR connects each of the processors directly to each other). In turn, nodes can be connected through another CROSSBAR network.

Valero has extensive experience in algorithms for systolic arrays. Some of the work has been supported by the Spanish Comisión Asesora para la Investigación Científica y Técnica (CAICYT). Some references to the work are Navarro, et al. (1987); Fernández, et al. (1989); and Valero-Garcia, et al. (1989).

## School of Civil Engineering

The School of Civil Engineering has a somewhat different structure than a department of the same name at a university in the U.S. The department consists of about 70 full-time faculty (there are part-time faculty members) and 1,000 students. The school is self-contained, and the faculty includes persons needed to teach mathematics, physics, statistics, as well as the usual engineers. The program in CE leads to a degree in professional civil engineering, requiring a small thesis as well as a civil

engineering project, taking 6 years to complete. The degree seems to be about the same level as a Masters degree, but not exactly equivalent. There are about 50 graduates per year.

I spoke with Professors Eduardo E. Alonso and Jesus C. Ramirez; the latter also serves as the subdirector for research. The areas of research at the school include numerical analysis, statistics, structural engineering, marine engineering and ocean dynamics, and geotechnical engineering. They described some of the research in the school. Research is supported by CAICYT, government agencies, and private industries.

Alonso works in geotechnical engineering, especially soil mechanics. He and his coworkers are attempting to formulate new methods to gain a basic understanding of the behavior of soil under the effects of nonhomogeneous structure, water flows, and hydration of active minerals and salts. An analysis of the effect of swelling rock on structures built on it is given in Lloret, et al. (1988). According to Ramirez, more work is necessary to understand the long-term behavior of such ground/structure problems in order to base decisions regarding the siting of power plants and other facilities on sound reasoning. Finite element techniques are used for the analysis of soil mechanics (see Gens, et al., 1989). In some cases computational complexity means it is necessary to solve a two-dimensional version of the equations (which, nonetheless, must take into account some 3-D effects). Modeling rock joints using a new type of constitutive law is being carried out. The law uses a nonassociated plasticity framework and seems to satisfactorily model different types of rock joint behavior. The yield function curves are based on a hyperbolic failure criterion. Results of the computations were compared with experimental results (see Carol, et al., 1986). Work is continuing on new types of constitutive relations for granulated materials in soil that is partially saturated by water.

## Conclusion

Barcelona is in one of the more affluent parts of Spain, and the amount of funding available for research seems to be adequate. The work in solid modeling appears to be state-of-the-art. The robot vision work is very interesting and seems potentially very useful. I was especially interested in the work which enables handicapped persons

to easily perform routine tasks on the computer. A more challenging goal is to enable the handicapped to do word processing with some ease. The work of the computer architecture group and the civil engineering school in nuclear power plant safety and the related power plant siting question is on a vitally important topic, as is the radar reflection work. The broad approach of the computer architecture group to the study of several architectures for various problems is somewhat similar to programs I have found elsewhere in Europe. The work on a new constitutive relation for granular materials has progressed to the point that Alonso expects there to be an international conference on the topic in 1991. The research I heard about at the Polytechnical University of Catalonia is being conducted in excellent programs and seems to be near the forefront of related activities.

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# MECHANICAL ENGINEERING

## An International Conference on Offshore Mechanics and Arctic Engineering at The Hague, the Netherlands

by Henry T. Wang. Dr. Wang is a research mechanical engineer in the Laboratory for Computational Physics and Fluid Dynamics at the Naval Research Laboratory, Washington, D.C.

### Introduction

The 8th International Conference on Offshore Mechanics and Arctic Engineering (OMAE) was held March 19-23, 1989, at the Congress Centre in The Hague, the Netherlands. This annual conference is concerned with the behavior of offshore structures operating in a wide range of environmental conditions. It was sponsored by 18 technical societies, mostly from Western Europe but also from North America and Asia.

The conference offered a range of activities for more than 600 attendees. Approximately 400 papers were presented in 71 technical sessions covering the following disciplines: production, operations, hydrodynamics, structural mechanics, materials technology, ice mechanics, pipeline technology, and computer applications. The scope of the papers ranged from applied to fundamental. In addition, there were social functions each evening, two formal luncheons, and a tour of the Netherlands Ship Model Basin at Wageningen. Because of legal difficulties encountered during the organization of this year's conference, the usual technical exhibit was cancelled.

### Hydrodynamic Forces and Motions

I will not attempt to summarize all the areas covered in the conference. Instead, I will give a review of the approximately 70 papers in the general area of hydrodynamics, highlighting those papers that should be particularly interesting. Information on ordering the six volumes covering all the papers is provided at the end of this report.

**Forces on Circular Cylinders.** Since the circular cylinder is one of the most widely used structural components of offshore structures, not surprisingly many papers were devoted to investigating the forces and motions of these structures. The forces of interest may be roughly subdivided into two groups: those in line (parallel) with

the environmental excitation (often obtained by using the well known Morison's equation), and those transverse (perpendicular) to the excitation caused by vortex shedding. The papers are largely concerned with the definition of the force coefficients as a function of either cylinder or environmental parameters. Examples of cylinder parameters include inclination to the current, aspect ratio, roughness, proximity to the free surface, motions, and presence of other cylinders. In the case of the environmental excitation, the papers treat such topics as the use of higher order wave theory, description of random wave fields, equivalent linearizations of the quadratic velocity term in the drag force, presence of different wave/current combinations, and presence of an upstream shear current.

Several papers use a direct solution of the Navier-Stokes equations to obtain the flow around two-dimensional circular cylinders. Of these, three will be briefly described to illustrate present day state of the art in this area. G.S. Triantafyllou, Massachusetts Institute of Technology, and G.E. Karniadakis, Princeton University, U.S., presented a calculation of the flow around an oscillating cylinder at the low Reynolds number  $Re$  of 100 by integrating the Navier-Stokes equations in primitive form in a coordinate system fixed to the cylinder. A hybrid spectral element is used that is claimed to combine the high accuracy of the spectral method with the geometry flexibility of the finite element method. P.K. Stansby and P.A. Smith, University of Manchester, U.K., presented a random vortex method to solve for impulsively started and oscillatory flows for  $Re$  up to 3,600,000. An eddy viscosity is used to model the turbulence at these high  $Re$ . The simplifying feature of this method is that, except near the cylinder wall, essentially potential flow methods may be used to calculate the trajectories of the vortices modeling the viscous flow field. At the cylinder wall, the authors claim that by using an absorption method, whereby those vortices that cross the cylinder wall are deleted in-

stead of reflected back into the fluid, the total number of vortices is substantially reduced. The penalty is that the new vortices that are created to satisfy the no-slip condition at the wall must undergo a more complex diffusion modeling.

M. Braza and H.H. Minh, Institut de Mecanique des Fluides, Toulouse, France, presented a finite difference method to solve the Navier-Stokes equations in primitive form, expressed in logarithmic-polar coordinates to conform to cylinder geometry. Values of Re up to 10,000 are considered. A widely used two-step procedure is employed to calculate the velocity field at each time step--first obtaining an approximate velocity field for an estimate of the actual pressure, and then obtaining corrected values that satisfy the condition of incompressibility.

**Forces and Motions of Other Structural Shapes.** Several papers experimentally determined the wave uplift force on structures with horizontal bottoms, and on structures located on or near the ocean bottom. T. Sawaragi, S. Aoki, and S. Hamamoto, Osaka University, Japan, presented two different approaches, both using Green's functions, for obtaining the forces on a ship confined in a harbor. First, assuming the harbor walls to be wedge-shaped with included angle equal to  $180/m$  degrees ( $m = \text{integer}$ ), the required harbor shape may be obtained by appropriately reflecting the singularity strengths modeling the ship. For example, a wedge angle of 60 degrees may be obtained by five reflections. For a harbor of more general shape, the flow is divided into three regions--the open ocean region, the harbor except near the ship, and the region near the ship. In each region, the potential is expressed as a series of Green's functions with unknown coefficients, whose values are determined by the conditions of no flow through the solid walls and continuity at the fluid boundaries between regions. W.G. Price and Y. Wu, Brunel University, Uxbridge, U.K., presented a paper on the time domain solution of the nonlinear response of flexible SWATH ships. This is illustrative of the current growing interest in nonlinear solutions of ship response as opposed to the traditional linearized frequency domain approach. A useful computational feature of their method is their reduction of the convolution time integral, arising because of the frequency dependent added mass and damping terms, to a series of regular integrals in ascending powers of the time lag. Their results show fair agreement between the nonlinear and equivalent linearized solutions. The agreement worsens, as expected, with increasing amplitude of the exciting wave.

**Higher Order Low Frequency Drift Motions.** The relatively large number of papers (approximately 12) devoted to this seemingly specialized topic indicate the considerable concern of the offshore industry regarding this area.

These motions are caused by second order low-frequency forces, which arise because of nonlinear interactions between wave components with neighboring frequencies. These second order forces are relatively small, but coupled with a lightly damped low-frequency resonant behavior of the structure, may lead to large motions. The main concern in these papers is to experimentally and/or analytically determine the exciting forces and motions of such diverse offshore structures as barges, semisubmersibles, compliant towers, moored ships, and ships close to each other. Typically, the second order forces are expressed in terms of interactions of first order potentials (thus neglecting the contribution of the second order potential itself), and the nonlinear response transfer function is given in terms of the lowest order quadratic response obtained by suitably transforming or filtering the measured or calculated motions. Perhaps the most novel paper was presented by A. Naess, Norwegian Institute of Technology, Trondheim, Norway. He shows that in narrowband responses, which is typical for slow-drift motions, accounting for the correlation between local maximum response values (instead of assuming them to be independent), may result in substantially lower predictions of expected extreme responses.

**Ocean Waves.** In addition to the papers specifically devoted to this subject (presented in two sessions), the ocean waves, of course, serve as the primary excitation in many of the papers discussed above. The papers in this area discuss the following aspects: predicting the design wave statistics at particular coastal locations (India, China, Norway), measuring techniques (use of an optical Moire fringe technique), design of a fullscale data buoy, description using higher order waves, modification of the ambient waves caused by the presence of a structure, and numerical or experimental modeling of the random sea.

I presented a paper describing the modification to the ocean waves caused by the radiation and diffractions waves around a surface ship. The use of a low-order simulation of the ocean waves facilitates the computation of the ship waves as well as their subsequent comparison with the ocean waves. The basic conclusion is that the ship waves make relatively small modifications to the ocean waves. J.C. Pan, Dalian University of Technology, Dalian, and B.Q. Xu, the Third Design Institute of Harbour Engineering, Shanghai, China, presented the useful observation that in an area where there are strong tides, it is necessary to give separate design wave heights for rising tides and ebb tides. These heights are obtained by first extracting the "pure" wave from measured waves (by regression analysis), and then using wave current interaction to predict the waves in different tidal conditions. They show that by using this method the design wave for rising tide is nearly twice as large as that for ebb tide in the mouth of the Yangtze River. C.T. Stansberg, Norwegian Marine Technology, presented a thought-provok-



ing discussion of the degree of randomness and complexity of various numerical simulation techniques such as direct summation of cosines, analog white-noise filtering, FFT methods, auto-regressive methods, and simulation of particular events. Basically, those methods that give better approximations to random behavior require the longer record lengths to obtain low statistical scatter. Regarding the differences in degree of randomness between the methods, the paper states that they "...may in a large range of cases mean nothing or very little, but the task to distinguish between cases where it is significant and where it is not, has not yet been clarified well enough."

### Conclusion

Taken as a whole, the Proceedings of this conference give a broad view of the latest worldwide research activities investigating the behavior of offshore structures. The individual papers give detailed information on current state-of-the-art procedures or give an initial exposition of novel concepts or techniques. The full manuscripts of these papers are reviewed and subsequently revised before presentation and publication in the Proceedings. Because of the large number of techni-

cal disciplines considered in this conference, the Proceedings are published in six volumes (see Table 1).

**Table 1**

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## OCEAN PHYSICS

### 21st International Liege Colloquium on Ocean Hydrodynamics

by Dr. Alan I. Weinstein, the Office of Naval Research, Arlington, Virginia, and B. Edward McDonald, Naval Ocean Research and Development Agency, Stennis Space Center, Mississippi.

#### Introduction

The 21st International Liege Colloquium on Ocean Hydrodynamics was devoted to Coupled Ocean-Atmosphere Models. The colloquium was held on May 8-12, 1989, in Liege, Belgium, and was attended by more than 50 scientists from Australia, Belgium, Canada, FRG, France, Hungary, Italy, Japan, the Netherlands, PRC, Spain, U.K., U.S., and U.S.S.R. The colloquium focused on global scale issues related to the El Nino/Southern Oscillation (ENSO). Fifty-two papers were presented, approximately 40 percent of which addressed or utilized ocean-atmospheric coupling parameters. The colloquium was a followon to one in 1984. Before considering the 1989 conference, it is helpful to summarize the 1984 conference.

In 1984, the 16th International Liege Colloquium on Ocean Dynamics was the first to be devoted to Coupled Ocean-Atmosphere Models. It consisted of 43 papers,

approximately two-thirds of which studied ocean response to specific atmospheric forcing, or vice versa. Only about one-fourth of the papers included some sort of interaction parameterization. Of these, only two attempted to couple oceanic and atmospheric general circulation models (GCM's). The modeling state-of-the-art at this time was not ready to attack a benchmark on the scale of the ENSO cycle. One problem that became evident in coupled GCM's was a discouraging downward climate drift in sea surface temperature (SST) and air temperature. On the whole, the field of interactive ocean-atmospheric modeling in 1984 was in its infancy, despite the proven record of separately developed atmospheric and ocean GCM's.

Returning to the 1989 meeting, Dr. R.W. Stewart, Institute of Ocean Sciences (IOS), Canada, started the colloquium on the optimistic note that ocean models are now approaching the point where predictions are possible.

Dr. Stewart noted that political decision-makers will take action based upon this prediction capability, and that this makes it incumbent upon the research community to express the level of uncertainty that exists in these predictions. As the conference unfolded, it became clear that this assessment of predictive capability was optimistic and his warning of uncertainty well founded.

One speaker likened ocean-atmosphere interaction to a marriage. The parties to this marriage exchange heat and have periods of elevated stress. At times, one member of the partnership is slave to the other, and at other times forces the other into action. Each member of the partnership has its own personality--the atmosphere impetuous, and the ocean rather reserved. The colloquium addressed the two partners separately before considering their marriage within a common modeling framework. The papers during the first two and a half days dealt primarily with responses of one medium to the other, with little concern for coupled interaction. The second half of the meeting did contain papers reporting varying degrees of success in modeling the ocean and atmosphere together. Approximately five of these addressed ENSO. Some promising signs in the model results appeared in the form of eastwardly propagating SST anomalies with time scales of order 2 years for crossing the Pacific Ocean.

## Atmospheric Dynamics

**Equatorial Dynamics.** Papers on the first day dealt largely with atmospheric response to SST anomalies. El Niño is a warm equatorial SST anomaly with a return period of approximately 4 years. It starts in the western Pacific and propagates to the east, arriving as a warm anomaly off Peru for the first year. The strongest El Niño in recent times was in 1982-1983 with a temperature anomaly of approximately 3°C. A less dramatic El Niño occurred in 1987 with a 1°C warming. Between the warm anomalies, there have been cold ones (called La Niña), occurring in 1984 and 1988.

Warm SST anomalies have two immediate effects on the atmosphere above them, increased latent heat flux, and increased convergence. Since atmospheric motion is in very delicate balance in the tropics caused by the prevalence of convection and the absence of geostrophic control, the warm SST anomalies quickly induce broad scale convergence of surface air. This convergence intensifies convective updrafts, causing increased condensation and ultimate precipitation. Condensation liberates heat, which intensifies the surface convergence. Hence, increased precipitation generally follows centers of SST warming. It is the convergence of surface air that is primarily responsible for the increased precipitation, rather than the simple increase in latent heat flux that comes from elevated SST.

**Midlatitude Dynamics.** The mechanism by which equatorial atmospheric responses propagate from the tropics to midlatitudes is not clear. In fact, not all model calculations propagate the response at all. When propagation occurs, it does so primarily in response to warm anomalies.

One suggested propagation mechanism involves the interaction of equatorially induced convergence with the jet stream. The suggestion is that the equatorial convergence interrupts the zonal pattern of the jet stream, increasing its wave number and making it more meridional in nature.

**Model Characteristics.** In time, increased equatorial convection leads to increased cloudiness and increased outgoing radiation. Radiation is the least understood and most complicated heat transfer process to calculate in the atmosphere. Hence, it is the weakest component of atmosphere models. Since radiation plays such an important role in tropical atmospheric motion, atmospheric models suffer in this region of the world.

Fortunately, the other atmospheric processes have been simulated numerically for over three decades in Numerical Weather Prediction (NWP) models in the mid-latitudes. Virtually all modern atmospheric models used for large-scale air-sea interaction research use the "primitive equations" (PE) of atmospheric motion. Such motions adequately simulate the relevant physical processes, with the exception of radiation.

## Ocean Dynamics

**Model P Characteristics.** In contrast to a long history with atmospheric P.E. models, ocean models are newer. The basic P.E. ocean model currently in use for research was developed by Bryan in 1969. Most of the conference papers involving large-scale ocean simulation used one of the variants of this model. Other models in use make physical simplifications typified by geostrophy, *quasi-geostrophy*, lumped-parameter *box ocean* approaches, and one- or two-layer approaches. Layer models relate the ocean evolution to horizontal motion within vertically homogenized layers, with moving layer boundaries describing the ocean surface and thermocline.

**Model Response.** Ocean models respond to atmospheric anomalies in wind and/or evaporation/precipitation differences. Wind stress provokes the quickest ocean responses, with timescales down to less than 1 hour (e.g., during passage of a storm). On the other extreme, the global thermohaline circulation operates on a much longer timescale. This circulation transports the ocean's heat horizontally, and is driven by density anomalies which can be caused by differential heating, evaporation/precipitation, or vertical mixing. The global circulation time for this current is on a decade scale.

**Wind Stress.** Wind increase anomalies have two effects on the ocean, stress convergence, and mixed layer deepening. Both effects strongly influence ocean circulation. The former is the principal factor in the wind-driven ocean circulation. The latter, along with evaporation and precipitation, contributes to the thermohaline circulation.

**Precipitation/Evaporation.** Precipitation and evaporation contribute oppositely to mixed layer processes which drive large scale circulation currents. Evaporation increases mixed layer salinity. Since saline water is more dense than fresh, increased salinity leads to increased convection, deepening of the mixed layer, and SST cooling. The reverse is the case where precipitation exceeds evaporation. Here the ocean freshens, convection is decreased, and the mixed layer shallows. Mixed layers deepening or shallowing sets up a horizontal pressure gradient that manifests itself in horizontal currents. This process is the principal component of the thermohaline circulation.

**Climate Drift.** One of the recurring issues reported with general circulation models is climate drift. Ocean and atmospheric GCM's using the P.E. approach solve their equations (at least in the vertical direction) by finite difference methods. Most finite differencing techniques introduce numerical diffusion to ensure smoothness and stability of the solution. Since the ocean has a large reservoir of cold water beneath a relatively shallow, warm surface layer, a numerical procedure that mixes this deep large cool reservoir with the shallow, warm one, tends to cool the surface temperature. This artificial diffusion of subsurface water into the mixed layer is a serious problem for ocean models. It leads to a cold bias or cold climatological drift. One of the ocean P.E. modelers referred to this problem along with the atmospheric radiation balance problem as contributors to potential "artificial ice age(s)" within coupled models.

**Coupled Interaction.** Although the colloquium was called specially to address coupled models, such coupling was not discussed until the third day of the 5-day meeting. Even then, only half the papers discussed true coupling.

Because of the complicated nature of each individual medium's response to the other, truly coupled models require enormous computer resources and/or considerable simplification. The latter greatly compromises reality and the former is very expensive. Hence, all of the papers on true coupling are filled with introductory qualifications such as "simplification" or "preliminary."

It appears that the models of each medium are sufficiently advanced, the interest in coupling is sufficiently high, and available computer resources are rapidly enough increasing so as to make true coupling attainable. The present attempts, however, are preliminary and findings are still tentative. The most persistent of these early

findings was that both models exhibit climate drift toward cooling. When coupled, this drift works together and eventually weakens the coupled system beyond reality.

Although the bulk of the colloquium papers dealt with Global Modeling, two concerned smaller scales. The first tied ocean and atmospheric boundary layer together to show rudimentary interaction on flux scales, where time and space scales of the two media are well matched. The second smaller scale paper dealt with hurricanes. Here it was reported that numerical calculations were consistent with what we already know: that hurricane winds cool the ocean below by stress-dominated mixing. This in turn reduces the latent heat flux into the storm and reduces the hurricane intensity. New findings were that the coupling effect is positively related to hurricane size and negatively related to hurricane tracking speed.

## Other Issues

Many factors other than those mentioned above contribute to the coupling of the ocean-atmosphere. Some of those touched upon during the conference were polar ice cover, global atmospheric albedo, and the greenhouse effect. These issues received varying degrees of attention, but in general were minority positions. Another potentially important topic not covered in the conference was the time and space scale mismatch between atmospheric and ocean processes. During question periods, the authors of the current article looked for specifics on how interface conditions are handled in light of this mismatch. Answers were short, comments indicating that fluxes are interchanged from one to a few times per day. Apparently, a framework for consistent flux exchange has yet to be investigated. It seems likely that the temporal and spatial scale mismatch between ocean and atmosphere will require special numerical/theoretical methods for proper treating of the interface. The relative importance of these issues will hopefully be clarified by work in progress during the next few years.

## Summary and Conclusions

At present, it appears that European groups have taken the most aggressive approach to coupled model development since the 1984 conference, leveraging progress from major programs in meteorological GCM research in the U.K., FRG, and France. The Americans still appear to hold the lead in ocean modeling, and are in close competition with the Europeans in model coupling. The Japanese, though representing only about six percent of the papers, appear to have a competitive capability in coupled GCM development. The Eastern Bloc countries, further behind, apparently reflecting limited access to computing facilities.

An appropriate summary of the 21st Liege Colloquium on Ocean Dynamics, devoted to coupled ocean-atmosphere models, was given by the author of one of the most complicated, yet realistic simulations. His first conclusion received widespread agreement. It was "Coupled Modeling is very difficult, but we are making progress." (This comment is appropriately augmented by a wry observation made at another point during the meeting: "When two bad models are coupled, it is possible to get a bad result?")

Progress will be made through a combination of better physical modeling, improved numerics, and larger computers. Physics improvement seems to be required to remove numerical diffusion in the ocean models. Larger computers will be required to allow both models to be run in sufficient time and space resolution to include all the relevant processes.

## PHYSICS

### High Magnetic Field Facilities and Research I: The Clarendon Laboratory, Oxford

by Dean L. Mitchell

The high magnetic-field facility of the Clarendon Laboratory at Oxford University dates from the years following World War II when Martin Wood, who later founded Oxford Instruments, headed an effort to develop magnets that could produce dc fields in excess of  $10^5$  Gauss (10 T). At that time, Francis Bitter at MIT was building high-field dc magnets according to an alternate design. "Bitter" magnets consisted of stacks of thin copper plates, interleaved to form a coil and placed under compression to prevent distortion during operation. Cooling was provided by water channels through the stack with the holes positioned to optimize the current distribution. Such magnets are inherently low impedance and therefore could not be matched to the Oxford 2-MW motor generator that was available for the magnet power supply.

Several magnet designs were developed at Oxford including tape-wound magnets, the discrete polyhelix magnet, and the layer-wound helix currently in use. Peter Hudson and Harry Jones were responsible for the latter design. The magnets developed at Oxford are quite successful and are well matched to the 2-MW dc motor generator. The design goals for the magnets were met or exceeded leading to the adoption of Oxford design concepts by other laboratories.

Although overtaken as a leader in high-field magnet technology by the much larger national and supranational laboratories in the U.S., Japan, and Western Europe, the Clarendon Laboratory has continued to develop as a premier user facility for research at Oxford. The theme has been to concentrate on providing convenient experimen-

tal access to a variety of magnets rather than attempting to achieve ultimate fields. The mix of magnets available includes resistive magnets, superconducting magnets, and hybrid combinations. The resistive magnets produce fields to 10T in a 50-mm bore or 13T in a 30-mm bore. The present hybrid magnet consists of a resistive core and outer superconducting coil and produces fields to 20T in a 30-mm bore. Fields of 24T will become achievable by adding a second hybrid magnet now under construction with the 10-11T superconducting outer coil being built by Oxford Instruments and the resistive insert being built at Oxford. Funds for the new hybrid were obtained from the Science and Engineering Research Council (SERC). The magnet laboratory also maintains a 16T superconducting magnet with 25-mm bore that is portable and can be wheeled to the site of an experiment, a feature not available for the resistive and hybrid magnets. A 17T/40-mm mobile magnet was ordered.

Harry Jones directs the magnet laboratory and is responsible for magnet development and operations. In this capacity, he is involved in several projects that will significantly augment the current facilities. The projects include acquiring and installing the 24T hybrid magnet mentioned earlier; participating in a joint, multinational wire development project funded by the Council-of-Ministers of the European Community (EC); and, developing a 60T pulsed-field facility at Oxford with SERC funds.

The wire project funded by the EC is aimed at developing practical conductors that can be used to fabricate reusable pulsed magnets with fields extending to 60-70T. Until recently, the maximum fields attainable with long-

pulse magnet coils were on the order 40-50T using copper conductors, cryogenically cooled to liquid nitrogen or liquid neon temperatures before each pulse. This situation has changed dramatically with the advent of copper composites with filamentary inclusions of Nb, Ti, or other refractory metals. The composites were developed as superconductors but also are useful for high-field magnets because of the increase in tensile strength provided by the filamentary inclusions. The increase in mechanical strength caused by the filaments more than offsets the decrease in electrical conductivity from that of pure copper. Coils with 5-10-msec pulses have generated fields to 68T at the Francis Bitter National Magnet Laboratory (FBNML) with a Cu:Nb filamentary wire developed by Supercon. The pulsed-field laboratory of the Service des Champs Magnétiques Intenses supported by Centre National de la Recherche Scientifique (CNRS) at Toulouse has succeeded in generating fields of 60T for pulse times of 100-200 msec without coil failure using a filamentary wire developed by Ahlstrom, a French manufacturer of electrical equipment. The CNRS achievement is significant because it demonstrates the feasibility of generating quasistatic fields with pulse times of the order of seconds.

The EC wire project was described to me variously by several of the high field groups in Europe. They hoped that this project would generate higher visibility and funding for high field research in the European Community. The wire project provided a well-defined, interesting research topic that could be a basis for developing modes for interaction and for developing a coherent approach for future proposals. Because Supercon wire for testing and magnet development in Europe is hard to obtain, there is interest in developing an alternate source for filamentary wire. This project will run for 3 years costing 700,000 ECUs (\$750,000). The participants include the magnet laboratories at Amsterdam (Netherlands), Grenoble (France), Leuven (Belgium), Oxford (U.K.) and Toulouse (France). Grenoble and Oxford presently produce only dc fields but plan to construct pulsed-field magnets in the future.

The Oxford researchers will concentrate on developing methods for fabricating and insulating high-tensile strength wires for winding high-field magnet coils. Jones has established an on-going collaboration with Harwell to fabricate stainless-steel jacketed copper wire with a rec-

tangular cross-section. This wire is well suited to winding multi-turn coils with uniformly distributed stresses. It also provides a relatively inexpensive high-tensile-strength wire for fabricating pulsed-field coils with peak fields of 50T. Magnet construction at Oxford typically uses wire with a rectangular cross-section that is insulated with a wind-on insulation such as Kapton and then wound into a multiturn coil with a total mass of about a kilogram. Care is taken to have uniform layers with uniform stress. The coils are wrapped with Kevlar for reinforcement and impregnated with epoxy under a combined vacuum and high pressure treatment.

Stainless steel jacketed copper wire coils have been constructed with wind-on Kapton insulation applied to the rectangular wire. The coils were tested to failure at the pulsed-field laboratory at Leuven, Belgium. Failure analysis indicated that the breakdown typically occurred at the end of the coil at the crossover between layers. There appeared to be no problem with the adherence of the Kapton insulation to the wire.

Coils wound with Supercon wire provided by Bobinger of AT&T Bell Laboratories also were tested at Leuven. The coil wound according to the Oxford design failed at 50-55T. An analysis of the coil after failure indicated that the breakdown was caused by poor bonding between the Supercon wire and the insulation. A coil wound with a stainless steel jacket for reinforcement also failed in the same range. These fields are below the 68T peak fields obtained by Foner at the FBNML so that improvements may be expected. Subsequent testing of wires subjected to many surface treatments and heat treatments in an ambient atmosphere indicate that the bonding problem was caused by oxides. Thus with proper preparation, the bonding of insulation to the filamentary wire should not be a problem.

In the short term, the studies of failure modes will likely concentrate on using steel-jacketed wire. The wire can be obtained at reasonable expense in quantities that will allow testing enough coils to failure so the important design parameters can be identified. In the longer term, the goal of the Oxford program is to understand the proper materials and methods of construction for magnets to be used in the pulsed-field magnet facility at the Clarendon Laboratory for which SERC will provide funds.

## High Magnetic Field Research and Facilities II: Amsterdam, the Netherlands

by Dean L. Mitchell. Dr. Mitchell is the Liaison Scientist for Solid State Physics in Europe and the Middle East for the Office of Naval Research European Office.

Research in high magnetic fields traditionally has been an area of special interest at the University of Amsterdam following the work of Zeeman in Magneto-optics and de Haas in magnetotransport during the early years of the twentieth century. Recent work has been centered in the 40T (Tesla) magnet facility located in the Natural Sciences Laboratory. The facility has been operational since 1969 with a pulsed-field magnet capable of producing 40T for pulse times on the order of a fraction of a second. The fields are generated by massive, steel-reinforced copper coils that are precooled to liquid neon temperatures before each pulse. The current is provided by controlled rectification of power drawn directly from municipal mains. Flat-field plateaus for periods up to 0.1 second are available for quasistatic experiments with other profiles programmable for specific experiments. The maximum peak-power load currently is 5.8MW.

The facility is heavily utilized by the in-house research program augmented by collaboration with visitors. Areas of emphasis have included precision studies of the Fermi surface of metals and alloys using the de Haas-van Alphen effect as well as studies of magnetization and magnetic phase transitions in rare-earth and actinide compounds. The systems studied typically require higher fields than available with dc fields which currently reach 30T.

The recent increase in interest in high magnetic field research arising from the discovery of new material systems with unusual high field behavior, such as the ceramic oxide superconductors, has spurred several high field laboratories to increase the maximum fields available for research. The Netherlands has a particularly large investment in high magnetic field research, considering its size, in that it supports two world class magnet laboratories--the pulsed-field laboratory at Amsterdam and the dc magnet facility at Nijmegen which has maximum fields of 30T. In order to protect this investment, a workshop was held at Nijmegen in 1987 to assess the outlook for research in high magnetic fields and to provide a basis for developing a national plan for future development. From this followed a cooperative plan to enhance the operational capabilities of both the Amsterdam and Nijmegen facilities. The ultimate goal is to provide user facilities meeting international standards as well as providing the magnetic fields necessary for in-house research.

Based on the recommendations of the study, the University of Amsterdam approved a study project in

1987 to determine the technical feasibility of increasing peak magnetic fields to 60T. A total of f. 400,000 (\$180,000) was granted from university funds for the 2-year study. The aim was to develop a realistic design for the magnet and define the requirements for the power supply. Preliminary discussions with municipal power authorities have been held to determine the effect such a magnet would have on the power grid with peak loads estimated at about 50MW.

The study has been completed and is being used as the basis for the proposals required to generate the f. 10 million, (\$4.5 million) which will be required for construction. The total, about \$4.5 million, is large by Dutch Science Foundation standards, even though the payments could be spread over 3 years. However, there is a general sense of optimism that it will be possible to assemble the funds although it is expected that it will have to be gathered in pieces. The sources are the Dutch Science Foundation, other government agencies, and industry.

The development of the 60T magnet will be the responsibility of Dr. Paul Frings, a recent graduate of Amsterdam who recently returned to Amsterdam from Grenoble, France, where he has been involved in neutron scattering research at the Institute Laue-Langevin. The facility will be housed in the Natural Sciences Laboratory of the faculty of Physics and Astronomy. Dr. W.C.M. Matens, former director of the magnet laboratory, is now director of the faculty of Physics and Astronomy administration. The overall manager of the 60T project is Professor J.J.M. Franse who is Vice-Chairman of the National Steering Committee for High Magnetic Fields as well as a group leader the physics section of the Science Foundation which is expected to provide funds.

The designs for the magnet and power supply for the 60T project are based on the same principles as the corresponding components of the current 40T facility. The present magnet system incorporates a copper coil which weighs about 200kg. In operation, the coil is precooled to liquid neon temperature before each pulse. The current to the magnet is supplied by controlled rectification of power from the municipal power lines via a 5-kVA branch cable. The new magnet will require a 50-kVA line.

The 60T magnet coil also will require wire with higher tensile strength than provided by the copper wire used in present magnets. Several options are available. Amsterdam is a participant in a multi-laboratory project sup-

ported by the Council of Ministers of the European Community which is aimed at the development of improved wire suited to use in magnets to 60T and above. Steel-jacketed copper wire and filamentary copper wire composites are currently under consideration but the final decision is being left open in order to take advantage of whatever advances are made before the wire choice must be made.

The total cost of construction is estimated at f. 10 million which includes f. 3 million for the magnet, f. 3.5 million for the power supply and f. 1.5 million for measuring equipment. A contingency fund of f. 1 million is included as is usual for such projects. The estimated time scale for construction depends on funds. However, the best guess is that the construction phase should be completed in about 3 years; i.e., fields should be available for research in mid-1992.

There is no comparable facility to the Amsterdam magnet in the U.S. The Francis Bitter National Magnet Laboratory, supported by the National Science Foundation (NSF), produces dc fields of 30-32T and pulsed fields to 50T for user research. The pulsed fields have recently been extended to 68T for experimental coils. However, the pulse times are on the order of 0.01 seconds which is an order of magnitude shorter than the Amsterdam pulse times. A recent NSF report on high magnetic field research and facilities carried out by a panel chaired by Fred Seitz and Bob Richardson included, among several others, a recommendation for construction of a long-pulse research magnet with peak fields extending to 70T for pulse-times on the order of seconds. The cost of the magnet and power supply is estimated to be \$10 million. The increase over the Amsterdam cost is caused by the inclusion of a dedicated power supply.

## Recent Research Activities of the Bassin d'Essais des Carènes at the Paris and Val de Reuil Centers, France

by Henry T. Wang

### Introduction

In March 1989, I visited the Bassin d'Essais des Carènes (STCAN/BA), the principal naval hydrodynamics research laboratory of France. Preliminary arrangements for the visit were made by Chief Engineer (ICA) B. Masure, the Scientific Advisor to ICA J.C. Dern, the director of STCAN/BA. ICA Masure, along with Dr. B.K. King, accompanied me throughout my visit.

The STCAN/BA has approximately 200 employees, of whom approximately one-fifth are scientists and engineers. In contrast to major American naval research centers, where fulltime personnel may be 10 times greater, and the proportion of scientists and engineers may be one-half to one-third. The STCAN/BA has two centers. The principal center, at which approximately 85 percent of the staff is employed, opened in 1906 and is located in a residential district at the southwestern corner of Paris. The other center, opened in 1988, is located amidst idyllic countryside surroundings at Val de Reuil, approximately 60 miles northwest of Paris. There is some talk that in the next 10 to 15 years the entire operations of STCAN/BA may be moved here.

My visit consisted of three parts--a seminar on computational ship hydrodynamics, a tour of the Paris facilities, and a tour of the new cavitation tunnels at Val de Reuil.

### Seminar on Computational Ship Hydrodynamics

Besides personnel from STCAN/BA, several scientists from research centers in the Paris area were also invited, including Mr. Eric Masson and Professor Daniel Euvrard, Ecole Nationale Supérieure de Techniques Avancées (ENSTA), located at Palaiseau, a suburb south of Paris. I discussed my recent work at Naval Research Laboratory on the evaluation of Green's functions for the radiation case of a translating oscillating source (in collaboration with Dr. E.W. Miner) and the wave resistance case of a translating nonoscillating source (in collaboration with Professor J.C.W. Rogers, Polytechnic Institute, New York). The work for the radiation case consists of an asymptotic far field evaluation and has been used to compute the wave pattern around surface ships. In the wave resistance case, a relatively simple robust calculation procedure has been developed for evaluating the entire Green's function.

Mr. Masson's talk was also on the wave resistance case. By a technique involving using the geometrical Radon transformation, he has converted the usual double integral representation of the three-dimensional case to single integrals in terms of the simpler two-dimensional Green's function. Masson pointed out that the evaluation of the resulting integrals requires techniques that are very

similar to those used in medical image processing applications. Currently, he is investigating their applicability to his problem. Professor Euvrard briefly discussed his current work aimed at proper evaluation and interpretation of the troublesome free surface line integral problem.

Dr. King discussed his work on developing a computer code for the time domain simulation of nonlinear ship motions, a timely research topic. Dr. King's main concern is the proper modeling of the dynamics part of the equations of motion and developing techniques for their efficient integration in the time domain. Evaluating the hydrodynamic forces, which involves troublesome convolution integrals, is simplified by assuming that the ship wetted surface does not change during the motion. Calculations using this preliminary approach show that in certain cases, the nonlinear model may predict substantially larger roll motions than the traditional linearized model. This may be caused by the smaller restoring moment of the nonlinear model.

### Facilities at the Paris Center

Though covering only 10 acres, the center contains the principal facilities required for ship hydrodynamics research and testing work--three towing basins, a rotating arm facility, a wave tank, two cavitation tunnels, and a wind tunnel. In addition, there are the required support facilities such as a shop for making hull and propeller models, a drafting section, offices providing design services for instrumentation and testing equipment, and a computer center. Most of the facilities are of relatively small size. The largest towing basin is only 220m long reaching a maximum velocity of 10m/s (19.4 knots), and the test section of the wind tunnel is only 0.8m x 0.8m. An exception is the rotating arm which has a diameter of 65m and a maximum tangential velocity of 9m/s. An interesting feature of the towing basin and rotating arm facilities is that by using heavily chlorinated water, which inhibits the growth of algae, adequate lighting can be installed in the working areas. The newly installed numerically controlled manufacturing procedure for propeller blades is so accurate that small discontinuities in the mathematical splines describing the blade shape are (unfortunately) faithfully reproduced.

### Facilities at the Val de Reuil Center

The new cavitation research center at Val de Reuil is located in a beautiful valley next to the Eure River. The closest city is the river port of Rouen, some 15 miles northwest. The research facilities currently consist of three cavitation tunnels. There is ample space to construct the remaining research facilities if the authorities decide to move the entire STCAN/BA here.

Dr. Yves Lecoffre, center director, conducted the tour of the cavitation tunnels. The first tunnel was the tunnel

hydrodynamique pour l'Etude des Méthodes d'Essais (THEME), which is used to check out instrumentation and try new measurement techniques. The medium-sized Petit Tunnel Hydrodynamique (PTH) is used to study the hydrodynamic characteristics of cavitation. This tunnel has a free surface test section with cross-sectional dimensions of 0.6m x 0.5m, with maximum flow speed of 15m/s. Here we were given demonstrations of laser Doppler velocimeter and stroboscopic lighting instrumentation in operation.

The principal tunnel is the large Grand Tunnel Hydrodynamique (GTH). It has two test sections: a smaller closed test section with cross-sectional dimensions of 1.14m x 1.14m (maximum flow speed of 20m/s), and a larger closed or free surface test section measuring 2m x 1.35m (maximum flow speed of 12m/s). Dr. Lecoffre pointed out the unique features of the GTH tunnel--purity of the water, strict control of the bubble size distribution entering the test section, and quietness of operation. The purity of the water in the tunnel, which is periodically drained and filled with specially purchased water, is preserved by a series of measures including filtering and ion removal techniques. The bubble size distribution is controlled by first removing all the bubbles produced in the test section in a downstream dissolving tank and then in a large resorber. Then the desired bubble nuclei distribution, whose sizes are carefully monitored by optical means and by using a Venturi tube, are injected into the water upstream of the test section. The quietness of operation is because of measures taken to obtain low speeds of flow (less than 2.5m/s) everywhere in the tunnel except in the pumps and, of course, the test section. With the planned installation of new honeycombs, Dr. Lecoffre feels that the fluctuating levels of the incoming flow may be reduced to levels that are acceptable for hydrodynamics investigations such as transition to turbulence and boundary layer measurements.

For the convenience of current and prospective customers of the center's facilities, there is a hotel on the center grounds and service including a car with chauffeur. Also, Dr. Lecoffre said that the current daily charge of approximately 80,000 francs for testing in the GTH tunnel is aggressively priced to attract usage. This charge is several times lower than the usual marine industry practice of charging daily rates that are typically 1/1,000 of the construction cost of the facility.

### Summary

These are both exciting and uncertain times at STCAN/BA. The new research facilities at Val de Reuil, under the energetic leadership of Dr. Lecoffre, offer the promise of innovative research in the hydrodynamic and acoustical aspects of cavitation. The determination as to whether all of STCAN/BA will relocate there will come



after the French authorities fully consider such diverse issues as the wishes of the present staff at the Paris Center, the available financial resources, and the desired future direction and scope of naval hydrodynamics research.

An important consideration will also undoubtedly be the near-term manner in which the present Val de Reuil Center is received by the national as well as international marine community.

## The 11th International Symposium on Ballistics

by Marco S. Di Capua. Dr. Di Capua is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research European Office. He is an experimental physicist on leave until August 1990 from the Lawrence Livermore National Laboratory of the University of California.

### Introduction

Professor E. Celens, the Belgian Royal Military Academy (Academy), organized and chaired the symposium at the Brussels Convention Center, May 9-12, 1989, with more than 500 scientists and engineers from 19 countries participating. It was the 11th of a series held at 18-month intervals. In October 1988, the 10th Symposium was held in San Diego, California, and the 12th will be in October 1990 at a yet-to-be-determined location in the U.S. sponsored by the American Defense Preparedness Association (ADPA, nd).

Professor E. Celens and his staff performed an organizational feat worthy of a military campaign managing details from floral arrangements on the dais to distributing at registration a comprehensive set of proceedings (Celens, 1989; 1800 pages in 3 Volumes). According to Professor Celens, the meeting service infrastructure of the City of Brussels Convention Center greatly eased his burden. Professor Celens felt honored that guests had taken the time and trouble to come from afar, and treated all of us accordingly. The staff of the meeting, mainly cadets of the Academy, shared this attitude and helped the participants at every turn.

As a Liaison Scientist for Physics, I was pleased to be lodged at the Hotel Metropole on Place de Brouckere. This hotel was the venue of the 1911 Solvay Physics Congress and remains unchanged to this day. With the participation of A. Einstein, J. Jeans, M. Curie, M. Planck, E. Rutherford, L. de Broglie, and others, the 1911 Congress launched a permanent change of man's viewpoint of the atomic and cosmological order. A photograph of the participants in the conference room (minus transparency and video projectors) hangs in the lobby. As for the question: who slept in Einstein's bed? ... that is for science historians to determine (Regis, 1987).

The Ballistics Symposium covered seven themes in oral and poster sessions:

- Propulsion dynamics
- Warhead mechanisms

- Terminal ballistics
- Wound ballistics and body armor
- Weapon identification
- Launch dynamics
- Flight dynamics

I review the first three themes in some detail and discuss some of the main issues in wound ballistics and body armor.

M. Fackler, a U.S. Marine Corps surgeon, encouraged me to choose the last topics because he is appalled at the amount of misinformation that exists, not only among the general public, but also among emergency room professionals, about the pathology and post-trauma management of gun shot wounds. I encourage readers who are interested in more details, or the other topics to obtain the Proceedings and list of participants from the chairman of the conference (Celens, 1989).

### Propulsion Dynamics

Richard Vitali, Director of Corporate Laboratories of the U.S. Army, set the tone of the propulsion dynamics session by discussing new developments that are breathing new life into the propulsion dynamics field that was recently viewed as archaic and stagnant. According to Vitali, for example, introducing a unicharge gun propellant promises two factors--reduction in personnel and logistical support costs coupled with increased effectiveness through higher rates of fire, higher survivability, reduced packaging, longer shelf life, and reduced storage costs.

Another exciting innovation is the regenerative liquid propellant gun (RLPG), (ESNIB 89-04:33). In this gun, a piston injects propellant in the gun chamber during the combustion cycle. The pressure in the combustion chamber pushes the injection piston and the projectile in opposite directions, bootstrapping the process. Vitali posed fundamental questions similar to those rocket designers faced in the late 1950's and early 60's with some added complications that I discuss later in this report. Among them are

- Monopropellants or bipropellants
- Fuel/Oxidizer combinations
- Reaction kinetics
- Stability of combustion
- Chemical compatibility of the propellant and by-products with the breech, nozzle and to a lesser extent, the projectile
- Commonality with other users (Diesel, kerosene (JP4))
- Safety and storability.

Other exciting propulsion options are Combustion Augmented Plasma (CAP), Electrothermal (ET), and electromagnetic (EM) propulsion for projectiles. The CAP promises to augment the performance of conventional propellants while EM and ET propulsive technologies could overcome muzzle speed limitations of chemical propellants.

These techniques share some common physics with electric rocket propulsion techniques developed in the mid-sixties and early seventies (Jahn, 1967). Electric propulsion system studies concluded that the promises of specific impulse (equivalent to muzzle velocity) did not warrant penalties imposed by the mass of power sources (including radiators), converters, energy storage and switching equipment for space applications; i.e., the power conditioning bottleneck. A shortage of missions requiring electric propulsion coupled with substantial investments required to solve the power conditioning bottleneck brought the whole field, at least for deep space missions, almost to a halt. Proposed Strategic Defense Initiative applications have renewed some interest in the field (Caveny, 1989).

According to Vitali, power conditioning is a vital issue in ground-based systems, where the issue of energy storage density limitations ( $\text{J m}^{-3}$ ) replaces the mass limitations issue in space applications.

**Regenerative Liquid Propellant Guns.** The propulsion dynamics session featured many contributions on RLPGs. Experimental contributions from Royal Armament Research and Development Establishment (RARDE), Ft. Halstead, UK, underscored the importance of propellant compressibility (G. Cook) and observations of combustion noise (T. Andrews). D. Warken, Ernst Mach Institute (EMI), Weil am Rhein, FRG, (ESNIB 89-04:31-34) presented measurements of the temperature rise of RLPG monopropellants during injection. Temperature rise is critical because it could lead to propellant self-ignition during the injection process. In another contribution, G. Klingenberg, EMI, presented results from a collaborative project with Ballistic Research Laboratories (BRL), Aberdeen, Maryland, and Dynamit Nobel, Koln, Federal Republic of Germany (FRG), on electrical ignition of monopropellants.

Theoretical work on RLPG at BRL emphasizes droplet formation (A. Horst) and a one-dimensional model of the breakup of a liquid jet (G. Wren). K. Kuo, Penn State University, who has a rocket propulsion background, developed a comprehensive model for the physics in the combustion chamber. Kuo's model includes droplet formation, and a gas phase that incorporates droplet vaporization, droplet burning, and gas turbulence. Kuo has completed his model which now awaits numerical solution to compare its predictions with experimental data.

Kuo emphasized the substantial differences in the physics of combustion in RLPGs and liquid propellant rocket engines. In the RLPG,

- Vapor and liquid phases coexist in equilibrium inside the chamber (chamber pressure critical pressure)
- Dynamic pressure and, the absence of surface tension above the critical pressure maintain the jet integrity
- The propellant decomposition no longer takes place in a dilute environment
- Nonhypergolic bipropellants are a great challenge since the usual mixing mechanisms are ineffective and new mixing mechanisms have to be found for jets of high momenta
- Compressibility of the liquid play a role in the physics at high injection pressures.

**Gas Guns.** Gas guns are still of interest. G Klingenberg, EMI, discussed the single stage gas gun as a ballistic simulator to study two-phase reacting flows at realistic pressures and temperatures (ESNIB 89-04:31-34). H. Bernier, CEA-DAM, Limeil-Valenton Center, France, presented a numerical code that predicts performance of two-stage gas guns whose predictions agree very well with experimental data. J. Gottlieb, University of Toronto Institute of Aerospace Studies, Toronto, presented results from a code that simulates a two-stage light gas gun at the Defense Research Establishment Valcartier Laboratory, Quebec. Gottlieb found excellent agreement with experimental data and remarked that optimization of gun performance demands substantial computer resources.

**Instrumentation in Propulsion Dynamics.** The propulsion session had interesting contributions on instrumentation devoted to pressure, temperature, and combustion dynamics measurements inside gun chambers.

P. Schweiger, AVL List GmbH, Graz, Austria, described integrated piezoelectric recorders with ranges up to 6 kbar. The AVL's self-contained gauge incorporates a battery pack, charge amplifier, A/D converter, and memory. The transducer waits for an event inside a gun barrel, records the pressure data during the event, stores the data in memory, and awaits recovery for a memory

dump. H. Houdard, SNPE Defense Espace, Vert le Petit, FR, displayed an innovative application of PVDF pressure gauges inside gun barrels with peak pressures of a couple of hundred of MPa, rise-times of a few ms and pulse durations as long as 30 ms. Klingenberg, EMI and H. G. The, Prins Mauritius Laboratory, TNO, Delft, discussed fiber optic gauges to record brightness temperatures in gun chambers. R. Salizzoni, Penn State University, demonstrated the effectiveness of flash X-ray images to determine the instantaneous burning rate of a propellant inside a gun chamber.

G. Kordel, Dynamit Nobel AG, Furth, FRG, has a novel electrical inductive ignition system for caseless and cased ammunition that overcomes the drawbacks of electrical ignition systems proposed in the past. A capacitor connects to a primary transformer coil in the breech of the gun through a triggered switch. Inside the cartridge, an exploding bridgewire shunts the secondary coil of the transformer. A third intermediate loop, or a magnetic circuit, links the primary coil in the breech and the secondary coil in the cartridge. This coil provides a great flexibility in disposing the primary and secondary coil geometries. Tests so far indicate that this electrical ignition system is well suited for repetitive applications.

**Other Propulsion Dynamics Areas.** The session also covered traditional areas of propulsion dynamics such as gun propellant erosivity, projectile design, issues in two-phase flow and boundary layers in internal ballistics, finite difference modeling of a reactive mixture of incompressible particles in a compressible fluid (P. Gronenboom, Pisces International, Gouda, the Netherlands), heat transfer in gun barrels and subsonic gun simulators, and 3-D simulations of interior ballistics using the PISCES hydrocodes.

## Warhead Mechanisms

The sessions on warhead mechanisms covered shaped charges and explosively formed projectiles (EFP). The main topics represent problems that remain unsolved despite almost a half century of research in the field—effective modeling of jet formation, breakup of shaped charge jets, and the role of constitutive equations in EFP modeling.

**Shaped Charges.** Elongation of a shaped charge jet, and the process of breakup according to M. Held, MBB, Schrobhausen, FRG, are fascinating as well as puzzling phenomena that defy a detailed physical explanation. It is surprising that, extreme deformations notwithstanding, the crystalline properties of the material still determine when the jet breaks up into particles and the shape the particles take. Held's talk was a good overview of the state-of-the-field and his paper has an up-to-date list of references on the subject. Held's opinion is that jet breakup is independent of strain rate and the most important

factors are still the distance the jet travels, the microstructure of the liner, and the dimensional tolerances of the liner.

L. Zernow, Zernow Associates, San Dimas, California, described experiments (supported by Naval Surface Warfare Center, performed at the S-Cubed Green Farm San Diego Facility) to recover intact jet fragments in a shaving cream-polystyrene target. A bonus of polystyrene foam recovery is that the length of the melted track provides a calorimetric data on fragment temperature at the time of recovery. Zernow compared this recovery method to others such as vertical launching of jets in air and fragment recovery in polystyrene-water targets.

Zernow showed that X-ray diffraction of soft recovered samples complements the inflight Z-ray diffraction measurements pioneered by F. Jamet at the Franco-German Research Institute (ISL), St. Louis, France (ESNIB 89-03:40-42). The fragments retain a memory of the microstructural processes of jet formation, jet stretching, and jet breakup. Zernow shares the view that jet formation is analogous to the plastic stretching and radial shrinking of a wire by a velocity gradient. This analogy, while not perfect, provides insights about the material processing that accompanies the deformation of a conical liner into a thin jet. Zernow's preliminary conclusions, which may be controversial, are that jet formation increases the interplanar spacings in the crystalline structure in all the principal directions and that this increase in interplanar spacings may be ultimately responsible for the breakup of the jet. According to Zernow, such insights will result in a better understanding of fundamental microstructural phenomena and pay dividends in improved performance of future shaped charge designs.

R. Brown, California Research and Technology, Pleasanton, California, described the advantages of the combination of analytical and numerical treatments of the jetting process in shaped charges. On one hand, analytical formulations are a cost-effective tool for shaped charge design. Computer intensive numerical calculations, on the other hand, not only can validate the simpler analytical calculations, but also yield valuable insights on the collapse of the liner and the trajectories of individual elements flowing from the liner into the jet and the slug.

Computers with large storage capacity allow finely-zoned, multimaterial finite difference calculations that yield new insights on jet formation. Brown's finite difference calculations show that Pugh's 35-year-old concept of partition of liner mass elements between the forward moving jet and rearward moving slug at the stagnation point, while adequate for shaped charge design is a misleading picture of the physical process of jet formation. Brown's finite difference calculations show that liner mass elements stretch as they reach the centerline, suggesting that Zernow's analogy between jet formation

and ductile drawing, where the stagnation pressure replaces the role of the die in ductile drawing, may indeed be correct.

N. Birnbaum, Century Dynamics, Oakland, California, (*ESNIB* 89-07:35-40) also calculates jet formation in shaped charges with a combined numerical approach that circumvents the large number of small zones (and short time steps) resulting from a finite difference modeling of the line. Such models require slow, memory intensive calculations. His AUTODYN program allows such calculations through interactive rezoning features. However, for design purposes, the code incorporates a model for the liner that updates the coordinates of each shell mass point at each time step by integrating the equation of motion resulting from the explosive pressure forces, internal shell forces, and inertia of the liner. Post calculation analysis improves estimates of the collapse angle and jetting parameters.

A. Lichtenberger, ISL, utilizes flash radiography of jets to establish how the composition and microstructure of the liner determine the maximum jet elongation achievable before breakup. His results show that the finest homogeneous microstructure that results from heat treatment of the liner after recrystallization produces jets of great stability. Parts per million of silver, which is highly soluble in copper, yield stabler jets. Lichtenberger concludes that elongated jets require copper with a low recrystallization temperature, a fine grain size, and a controlled amount impurities. As an example, phosphorus in the ten part per million range produces smaller grain sizes. High purity copper, in the other hand, may result in undesirable higher grain sizes.

According to R. Caligiuri, Failure Analysis Associates, Palo Alto, California, powder metallurgy could deliver a significant cost reduction in the manufacture of dense metal (such as tantalum) shaped charge and EFP liners. The advantages of such a technique lie in fabricating a shape that is very close to the final desired shape. Moreover, this technique allows a very close control of impurity levels, an ultrafine and homogeneous grain structure, and has the potential to produce novel alloys; i.e., alloys that are normally immiscible or alloys of metals with highly disparate melting points. This research, sponsored by Defense Advanced Research Projects Agency (DARPA) and Army Research Office, has the goal, in the next phase, to produce liners for range testing. Imperfections in the liner and density gradients in the explosive have important effects in the quality of the jet. Several papers in the conference addressed these important issues.

J. Nicholson, Hunting Engineering, Amptill, U.K., demonstrated that typical manufacturing tolerances produce insignificant changes in axial velocity. However, the same imperfections can produce lateral velocities in jets as large as  $100 \text{ m s}^{-1}$ . Lateral velocities result from a momentum imbalance from nonuniform elements of the

jet originating at different azimuths of the liner. The calculations of Nicholson predict the lateral velocities that result from given imperfections.

P. Chi Chou's, Dyna East Corporation, Philadelphia, showed that analytical and numerical calculations predict jet rotation that originates with material anisotropies in the shaped charge liner. Jet rotation will occur when the principal axes of the liner material and the liner coordinates are oblique. Compression of the liner with this layout causes shear (shear coupling) that produces a counter-rotating jet and slug (angular momentum of the jet-slug system must be conserved).

Finite difference calculations of M. Murphy, Lawrence Livermore National Laboratory (LLNL), Livermore, California, addressed the effect of density gradients in HMX/TNT explosives and concluded that radial gradients produce drift velocities of the jet while axial gradients have little effect in charge performance. A predictive ability of the calculations would be desired.

M. Mayseless, Rafael Ballistics Center, Haifa, Israel, proposed that jet elements breakup at a distance that is a simple function of the initial jet radius, the strain rate, the radius of the jet at breakup, the average velocity of the jet, and the initial distance where the element joined the jet. This approach needs some refinements that would allow an a-priori determination of jet radius at breakup, a quantity that in Mayseless approach is an input from experimental measurements.

P. Chanteret, ISL (*ESNIB* 89-03:42) addressed a very practical question in warhead design; i.e., the minimum clearance volume between the charge and the guidance package (located fore of the liner) that allows adequate jet formation. Chanteret performed parametric hydrocode calculations and analytical calculations to formulate semiempirically a simple equation that relates the half angle of the clearing conical volume fore of the liner, explosive properties, and the half angle of the shaped charge liner.

W. Walters, BRL; S. Miller, Rafael; and, M. Ravid, Israeli Ministry of Defense, Tel Aviv, Israel, identified, in a lively post-session discussion, manufacturing precision of the liner as one of the key determinants of the jet breakup length for a given charge diameter. Charge performance is an economic issue linked to high precision, mass production of dense metal liners. For EFP's (see below) the issues are similar with the added complication that the prediction of the projectile shape requires knowledge of strain rate-dependent constitutive equations (*ESNIB* 89 07:35-40). Reproducible composition and microstructure of the liner material is another issue affecting high performance shaped changes. Trace elements in the part per million range, as discussed before, have pronounced effects in the microstructure. Present metallurgical processes are not able to deliver metals in large quantities at

reasonable cost with demanding impurity levels that are challenging even for reagent-grade laboratory chemicals.

**Explosively Formed Projectiles.** The EFPs differ from shaped charges inasmuch as the liner is a shallow spherical cap (subtending a small solid angle) with a varying thickness rather than a cone. Moreover, a heavy casing surrounds the explosive (ESNIB 89-04:33). The thickness of the liner as a function of radius determines whether the liner folds backwards (BF), collapses radially (RC), or folds forwards (FF). Therefore, EFP charges eject a projectile as opposed to a metal jet.

S. Miller's presentation on EFP's (Rafael) is a clear didactic primer on EFP design. Miller gave some very good physical insights on why successful formation of the projectile requires length-to-diameter ratios of the charge equal to unity; thickness-to-diameter ratios of the casing equal to a few percent; radial distributions of thickness that result on BF, RC, or FF projectiles; and adequacy of point initiation of the explosive. In very simple terms, he described how the liner gains a higher velocity at axial positions and why the initial curvature of the liner produces an inward radial acceleration.

Miller then introduced the radial collapse and stretching of a metal tube as a simple analogy to the final phase of EFP formation. This suggests the existence of an optimal ratio of radial and axial kinetic energy to form a projectile of the desired shape.

Miller uses the energy concept to analyze EFP formation. The integrals of the kinetic energy associated with radial motion (RKE) and the kinetic energy associated with axial motion (AKE) describe a trajectory in the AKE-RKE plane. Miller demonstrates that a locus in this plane separates stable and unstable projectile formation processes. Miller's presentation is a beautiful example of simplification of seemingly intractable problems by the power of physical insight.

D. Baum, LLNL, compared DYNA 3-D calculations of EFP shapes and experimental data obtained with an asymmetric liner. Good agreement between the calculated and measured shapes throughout the liner formation process requires rate dependent constitutive equations in the finite element calculation (ESNIB 89-07:35-40).

Honeywell Inc., Medina, Minnesota, contributed two papers on EFP. Authored by E. Fisher, one of the papers described how Kalman filtering can be applied to perform a multi-parameter interpolation between simulations to obtain a local optimum of projectile shape. K. Doeringsfeld described an entirely different approach where analytical equations describe the radial collapse and axial stretching of an EFP liner. Some of the concepts are quite similar to those of Miller, whose approach provides deeper insights.

## Terminal Ballistics

Terminal ballistics comprised about one third of the conference. Presentations covered penetration of projectiles such as jets, fragments, rods, and EFP's in metallic, composite, ceramic and explosive targets. Papers discussed hollow targets and targets backed by liquids as well.

**Surveys of Penetration.** W. Walters, BRL, presented an updated version of a recent survey paper of shaped charge jet penetration models (Walters, 1988). In his conclusion, Walters stresses that comparison of the relative accuracy of different models is exceedingly difficult because the rate-dependent constitutive equations of materials are unknown or because penetration models depend on semiempirical parameters particular to a given target penetrator configuration. Walters' contribution, rich in complete references with titles (111 in total, through 1988), is a welcome contribution to the conference and proceedings.

J. Backofen, Briggs Co., Herndon, Virginia, presented a new description of the penetration process that recognizes that a high velocity ( $> 10 \text{ km s}^{-1}$ ) impact produces a shock wave that compresses and accelerates the target material and compresses and decelerates the projectile as well. However, he emphasizes the difficulties he encounters, which are common to the community, to compare his predictions to experimental data and to predictions by other authors. Backofen has also been extraordinarily conscientious with his references (1983 through 1986).

**Penetration of Jets.** D. Yaziv, Rafael, compared measurements of the penetration of a precision shaped charge jet into monolithic targets and analyzed the data with a modified Bernoulli equation that includes the effect of material strength. Electric screens imbedded in the target determined the penetration velocity. The semi-analytical model, based on the common assumption of a liquid jet (no material strength) with a linear velocity distribution, provides an integral relationship between the jet element velocity, its velocity of penetration, and the time. A modified Bernoulli equation with a small material strength parameter compared to the dynamic pressure of the jet provides a second relationship between jet and penetration velocity. Simultaneous solution of both equations yields the penetration velocity as a function of penetration with the target strength as a parameter. A single strength parameter should describe target penetration for a range of projectile densities and velocities. The strength parameter that fits the data is a very sensitive function of jet length--a 5 percent error in jet length results in a 25 percent error in target strength parameter. The target strength parameters fitted over a penetration velocity range from 3 to 1 mm  $\mu\text{s}^{-1}$  are 2.9 GPa for mild steel and 4.5 GPa for RHA steel.

**Impact of Laminates.** Two authors discussed the impact of layered targets. I. Crouch, RARDE, developed a model for laminated target penetration that accounts for the shear fracture of the laminae in the impact side and debonding, bending, and stretching deformation of the rear laminae. Crouch emphasizes that some of the assumptions of the model are empirical, based upon observations of laminates that failed under impact. However, his model provides a mechanical picture of the failure model and highlights the properties that must be measured to predict ballistic performance. M.J. Simmons, Royal Military College of Science, Shrivenham, U.K., in collaboration with I. Crouch, developed a promising technique to measure, under controlled conditions that parallel those of ballistic impact, the energy required for bulge formation and delamination of composites. With this method, Simmons has formulated a semiempirical equation that predicts the force or energy that produce a bulge of given dimensions in the composite. According to Simmons, this testing procedure will reduce the requirement for ballistic experiments and will allow comparison of laminate composite systems. (See also ESNIB 89-07:39-40.)

**Impact of Plates with Low Density Backing Materials.** The impact of plates backed by lower density, lower strength materials is of practical importance in the penetration of containers for energetic materials such as fuel tanks, rocket casings or gun cartridges. S. Finnegan, Naval Weapons Center (NWC), China Lake, California, compared impact of backed as well as unbacked targets concluding that the backing reduces projectile fragmentation at impact velocities above  $1.5 \text{ km s}^{-1}$ . J. Yatteau, Applied Research Associates, Lakewood, Colorado, examined fragment deceleration, deformation, and fracture that occurs in the impact of water-backed plates. The objective of the work is to understand the deceleration of the fragment in the first ten or so centimeters behind the plate. Tests involved 1.25 cm steel cubes impacting aluminum plates between 0.6 and  $1.5 \text{ km s}^{-1}$ . Air is a low density backing as well. M. Alexander, NWC, revisited the question of why fragment impact of unpressurized compartments in aircraft can lead to structural failure. In his study, Alexander concludes that the energy loss of projectiles with velocities above  $1.6 \text{ km s}^{-1}$  produces a 0.2 - 0.5 bar over-pressure in a volume of a few tenths of a cubic meter. In the case of Al compartments, combustion energy of the Al target fragments can add significantly to the overpressure.

**Impact of Explosives.** Several papers discussed the behavior of explosives under impact. From the viewpoint of shaped charge jet disruption, the aim of J. Brown's work, RARDE, is to defeat explosive reactive armors by shaped charge jets and to increase the effectiveness of explosive reactive armors at more normal jet incidence. Brown determined experimentally that tamping of the

armor explosive by steel plates is a method that disrupts shaped charge jets at normal incidence. The disruption probably originates with the passage of the jet through the turbulent flow of explosion byproducts. J. Hubbard, RARDE, performed projectile tests on a wide range of munitions ranging from shells to 450-kg general purpose bombs. In general, penetration of the shell caused deflagration of the explosive. The effect of nonpenetrating projectiles ranged from no damage to deflagrations and detonations.

**Penetration of Long Projectiles.** The penetration of rod projectiles at high velocities was also widely discussed at the conference. M. Forrestal, Sandia National Laboratories, Albuquerque, studies penetration of geological targets with 40 mm-long 7 mm-diameter projectiles at normal and oblique impacts at velocities of  $3 \text{ km s}^{-1}$ .

R. Cline, LLNL, reported on a three dimensional surface that relates penetration, projectile shape (length to diameter ratio) and penetrating speed for a constant projectile kinetic energy. Cline determined these surfaces by a combination of modeling and experimental data. He expects to extend the data to tungsten penetrators in steel and to tungsten carbide and titanium carbide cermets impacting Pyrex. This approach is very promising to compare modeling and experimental data from different laboratories.

P. Naz, ISL, measured the crater diameter resulting from impact of copper projectiles launched by a light gas gun against mild, RHA, and high strength steels with velocities in the range of 2 to  $6 \text{ km s}^{-1}$ . Naz simulated the impact with the Hull code, originally developed by D. Matuska at the U.S. Air Force Armament Laboratory, Eglin, Florida. Naz shows good agreement between the calculations and the experiments. A review of the work at ISL (ESNIB 89-03:40-42) discusses some of Naz's work in more detail.

**Penetration of Segmented Projectiles.** J. Kivity, Rafael, and E. Hirsch, Israeli Military Industries, Netanya, Israel, attempted to quantify the difference in performance between segmented projectiles and long projectiles of equivalent length using a computational strategy similar to one they used to investigate the penetration of long jets. They applied the PISCES 2DELK hydrocode that treats multimaterial flows in Eulerian coordinates, and which is known to yield accurate results for deep penetrations. The presentation outlines very clearly the assumptions and boundary conditions for the calculation. The results of the calculation display the primary penetration of the projectile as well as the penetration due inertial motion of the crater wall. Kivity saw a new effect for the first time--a recovery phase where the crater wall springs back through elastic displacement.

Kivity compares the penetration of segments with the penetration of a rod with the same mass and finds that at higher velocities ( $> 5 \text{ km s}^{-1}$ ) the penetration of the seg-

mented rod is about 20 percent higher. He also presents a comparison of the penetration of rods with a modified Bernoulli equation, and penetration of segments by incorporating the effects of material strength into the well-established analysis of Christman (1966) which already has hydrodynamic and residual penetration. As in the case of other Rafael papers at this meeting, Kivity's presentation clearly outlines the assumptions and provides models that yield valuable insights on the finite difference calculations.

**Penetration of Ceramics.** I. Mellgard, Swedish Defense Research Establishment, Tumba, Sweden, determined the ballistic performance of ceramics by confining the ceramics in a steel assembly. She feels that this method, while differing from realistic designs, allows performance comparison of ceramic materials.

M. Ravid, Israeli Ministry of Defense, Hod Hasharon, Israel, presented a model for penetration of ceramics backed by metallic or composite plates. Penetration, according to Ravid's model, takes place in five stages--impact, projectile erosion in the ceramic medium, fracturing of the ceramic caused by shock propagation (ESNIB 89-07:35-40), penetration of the projectile in the fractured material, penetration of the projectile in the backup plate, and perforation of the backup plate. Ravid develops analytical models for each stage that allow him to predict armor performance that agrees with test results.

**Projectile Ricochet.** The interaction of the target in the impact of squat projectiles produces a torque about the center of mass of the projectile. J. Falcowitz, Rafael, described a very illustrative model that follows the motion of the projectile as it impacts the target. Falcowitz can model a projectile with any combination of obliquity and yaw angles, impacting multiple contiguous or spaced layers. The model clearly shows refraction in the projectile trajectory followed by total reflection at a constant incidence angle for increasing target thicknesses.

According to Z. Rosenberg, Rafael, the ricochet mechanism for long projectiles depends on bending of the projectile during impact, as opposed to turning of the projectile by a torque as in the case of squat projectiles. Rosenberg's analysis assumes that long projectiles bend successively in the process of impact. The model yields a locus in the obliquity-impact velocity plane that separates penetration from ricochet. Good agreement between the analysis and experiments indicates that the concept of bending is correct. Rosenberg clearly states his assumptions, compares his model with previous models, and provides needed insights on the physical processes during projectile impact and on the limitations of his analysis. In a companion paper, Rosenberg also discussed the yaw rates of long steel and tungsten penetrators at normal impact. The yaw arises from an asymmetric erosion or breakage of the nose of the projectile. Even small initial

yaws ( $<1^\circ$ ) can enhance asymmetric erosion or breakage.

## Wound Ballistics and Body Armor

Professor Celens discussed the motivations for the body armor and wound ballistics session emphasizing the importance of body armor for civilians (political and religious leaders, as well as ordinary citizens) and forces of public order (Secret Service, Police, Drug and Customs Agents) who face increasing threats from bandits, drug traffickers, fanatics, and terrorists. Professor Celens believes in understanding body armor in the context of the biological effects of bullets and fragments so he solicited talks on wound ballistics as well.

**Wound Ballistics.** M. Fackler, Letterman Army Institute of Research, San Francisco, discussed the effects of penetrating projectiles in the human body as a starting point to compare wound treatment methods as well as to plan battlefield surgical support.

Fackler simulates human tissue with refrigerated gelatin (10 percent solution,  $4^\circ\text{C}$ ) to measure projectile effects in live tissue. The gelatin reveals the perforation of the projectile. Cracks in the gelatin are excellent indicators of the tissue stretch that occurs in the temporary cavity caused by the bullet (Fackler, 1988). The temporary cavity forms for a few milliseconds when tissue stretches when accelerated by the shock wave of the projectile.

Fackler has calibrated the gelatin technique with results of autopsies where the weapon, bullet, and range of fire were known. The technique is sufficiently accurate to determine the residual power of projectiles after they have passed through intermediate targets such as body armor, wood, wallboard, and plastic layers. Experimental results with gelatin permit the expert a choice between ballistic scenarios proposed in a court of law.

The gelatin technique has also been validated with experiments on anesthetized domestic pigs. Fackler believes that animal experiments are also essential to train surgeons on life-saving wound management techniques applicable in battlefield as well as trauma centers.

**Body Armor.** Presentations and discussions at the session revealed that controversy surrounds the usefulness of body armor against projectiles launched at close range by modern assault weapons. Body armor absorbs part of the kinetic energy of the projectile by stretching or deforming plastically. It can also deform the projectile or fragment in the perforation process. According to J. Bretau, Institut de Medicine Tropicale, Marseille, the probability is high that the altered trajectory of the deformed, fragmented lower kinetic energy projectile may cause more damage than the unaltered trajectory of the high speed projectile would.

Bretau also discussed momentum transfer to the body of the wearer through the armor. This transfer produces



local accelerations as large as 300 G which last tens of ms. Local accelerations can produce blunt trauma with lethal effects in the cardiovascular system ranging from hemorrhages to reflex cardiopulmonary arrest.

Bretau also collaborated with P. Jourdan, Neurosurgeon of Military Hospitals, Paris, on a review of body armors in battlefield conditions and the protection they offer against shrapnel and light weapon bullets. Jourdan reviews very systematically metrological techniques that could deliver reproducible results at several laboratories, investigation of biological effects that may yield surprising results to ballisticians and engineers, and ergonomic studies under exertion in extreme climates. Finally, Bretau reiterated the importance of collecting clinical data from accidental shootings to determine the effectiveness of body armor under field conditions.

## Conclusions

1. Future development of RLPGs awaits a detailed understanding of the processes that take place in the gun chamber. These processes are different from any others encountered in powder guns, internal combustion, engines or rocket motors.
2. There is an urgent need to understand the microstructural evolution of the liner material in shaped charge jet formation.
3. There is also a need to incorporate rate-dependent constitutive equations in the modeling of EFPs.
4. The effect of target strength in projectile penetration is better understood. Experimental methods to measure this parameter appear well established.

5. The Rafael presentations are an example of effective coupling of experimental observations, numerical calculations and physical modeling. This approach deserves imitation at other centers.

6. Development of body armor and studies of wound ballistics raise ethical issues that the groups at San Francisco and at Marseille appear to have resolved. Gelatin is an effective simulation medium to test some of the effects of projectiles that perforate body armor. Gelatin-filled, instrumented mannequins can measure accelerations under impact conditions.

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# Hirschegg 1989 -- High Energy Density Production in Matter by Heavy Ion Beams

by Marco S. Di Capua

## Introduction

The Hirschegg 1989 meeting, organized by GSI (Gesellschaft für Schwerionenforschung mbH, Darmstadt) took place on January 29-February 4, 1989, at the Waldemar-Petersen-Haus, a mountain lodge belonging to the Technische Hochschule Darmstadt (THD), Technical University of Darmstadt, FRG, in Hirschegg, Klein Walsertal, Austria. The meeting continues a series on the general subject of Heavy Ion Fusion (HIF) that began in

1980 at Ringberg castle (Tegernsee) and later continued at Neuenkirchen (Odenwald).

The Hirschegg HIF community meeting workshops are forums for informal exchange of information, encourage international visitors to contribute new results and ideas, and allow young scientists the opportunity to develop personal contacts. In this respect, the series and the Gordon conferences have much in common: the chairman sets the main themes and chooses a limited number of participants (about 50), there are ample op-



portunities for the exchange of timely information, and a lodge facilitates interactions by furnishing informal, full board accommodations.

The theme of Hirscheegg '89--High Energy Density Production in Matter by Heavy Ion Beams--reflects a continuing maturation of the German HIF effort. Dr. Rolf Müller, of the German energetic heavy ion research facility GSI, organized the meeting. The Conference Support Program of Office of Naval Research European Office aided this workshop that included participants from Germany (36), the U.S.S.R. (3), France (2), U.S. (2), Israel (2), Japan (1), Australia (1), India (1) and Poland (1).

The interaction of heavy ion beams with matter opens a new field, heavy-ion plasma physics. The broad physics spectrum of this field includes

- Beam-plasma interactions in high energy density regimes
- Properties of dense plasmas
- Spectroscopy in the VUV and X-ray spectral regions
- Equations of state of hot dense matter
- Radiation transport at keV temperatures.

The workshop lectures themes were

#### Beam Plasma Interactions

- Calculations of energy deposition in plasmas by heavy ions
- Beam-plasma interaction experiments
- Particle beam focusing properties of plasmas.

#### Properties of Dense Plasmas

- Spectroscopic diagnostic techniques
- Charged states in high energy density matter
- Equations of State (EOS)
- Radiation transport
- X-ray emission
- X-ray lasing schemes.

#### Collision Phenomena

- Charge-exchange collisions
- Ion-ion collisions
- Collective effects.

#### Computational Physics

- Radiation Transport
- Hydrodynamic Instabilities
- Particle-in Cell (PIC) codes
- Target physics.

The workshop is best understood in the context of the German HIF effort so I briefly overview the German HIF effort first. I follow with the summary of Hirscheegg 1989 that I hope captures the excitement and youthful vigor of this new community.

The HIF has been the subject of a recent *ESNIB* article (Haber, 1989) that overviews the international symposium, held at Darmstadt in June 1988 (Bock, 1988).

## The German HIF Effort

In Germany, the HIBALL conceptual design for HIF has been carried out within the framework of a program funded by German Federal Ministry for Science and Technology (BMFT). A recent review by Bock (1988a) describes the current status of the program.

The program began with an exploratory phase (1979-1986) devoted to system studies of the HIBALL concept and, theoretical investigations of accelerator and beam target interaction issues. These studies were performed with the participation of GSI Darmstadt, Kernforschungszentrum Karlsruhe (KfK), Max Plank Institut für Quantenoptik (MPQ) Garching, Fraunhofer Gesellschaft Institut für Lasertechnik Aachen (FhG), and several German universities.

In the HIBALL concept, heavy ions drive a thermonuclear pellet to ignition. Heavy-ion RF-linacs that deliver currents in the order of 100 mA produce energetic (multi-GeV) heavy ions (50 MeV/nucleon). The linacs feed accumulator and buncher rings that shape pulse trains that deliver 20-ns wide, 5-MJ bunches to target pellets at 20-Hz repetition rates. These energetic pulses are the energy source to compress and heat pellets to thermonuclear ignition conditions.

The concept for the experimental facility, which would broaden the experimental data base, was developed in 1983 and construction was authorized in May 1985. The facility would incorporate a heavy ion synchrotron (SIS), shared with the nuclear physics community. See Figure 1 (Kienle, 1988). Additional equipment consisting of a high current injector for high intensity operation of SIS (Müller, 1986) and a experimental storage ring (ESR) with electron cooling to reduce beam emittance (Hofmann, 1983) would allow

- Investigation of beam dynamics at space charge limits
- Verification of particle loss mechanisms through charge exchange collisions
- Generation of low emittance beams

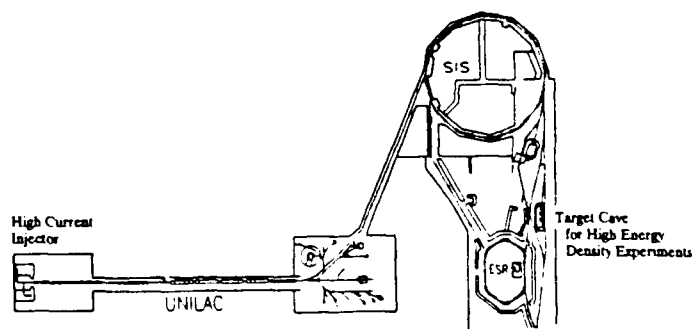


Figure 1. The GSI accelerator configuration including the new heavy ion synchrotron SIS and the storage ring ESR with electron

- Creation of high energy densities in matter.

Bohne (1988) indicates that SIS was nearing completion in mid-1988, had a projected startup date of April 1989 and availability of the beam at full energy to users in October 1989. The ESR capable of stacking, cooling, and bunching low intensity Xe beams injected by many cycles of SIS is expected to be operational in 1990 (Hoffman, 1989).

### Interaction of Heavy Ions with Matter (theory)

Deceleration of heavy ions heats the outer layers of the HIF target. Since this heating is the single most important, and perhaps most difficult problem to treat in HIF, from theoretical as well as experimental viewpoints, a substantial fraction of the workshop was devoted to discussion of heavy-ion--matter interactions.

The problem is difficult because, as the energetic ions slow down and may even become neutrals at rest, the initially cold target becomes an energetic plasma. The following factors are important in this process

- State of the target (bound electrons in cold target atoms or free electrons in plasma targets)
- Charge of the ion projectiles
- Energy (speed) of the ion projectiles
- Temperature of the plasma target electrons
- Number of electrons in the Debye sphere.

A theoretical overview of the interaction of heavy ions with matter, delivered by Dr. Thomas Peter, MPQ, is the topic of his recent doctoral dissertation (Peter, 1988).

Energetic ion projectiles deliver their energy to cold target atoms mainly through ionizing collisions with the bound electrons. Hence, the energy loss per unit length is

- Proportional to the number density of atoms in the medium
- Proportional to the square of the charge of the ion projectile
- Inversely proportional to the square of the projectile velocity
- Proportional to the logarithm of the ratio of the electron energy (center of mass frame) to "typical" ionization energies (Leighton, 1959; Evans, 1955).

Energetic ions with velocities greater than the electron thermal velocities also deliver their energy to the free electrons of a plasma by exciting plasma waves. The prefactor in the expression for the energy loss per unit length in a plasma is

- Proportional to the number density of plasma electrons
- Proportional to the square of the charge of the ion projectile

- Inversely proportional to the projectile velocity squared.

In this plasma case, the logarithmic term is the ratio of the electron energy (center of mass frame) to the  $\hbar\omega/2\pi$  associated with a plasma wave.

For ion velocities below the electron orbital velocity but above the thermal velocity of the plasma electrons, the logarithm involves the ratio of the electron kinetic energy (in the ion rest frame) to the electrostatic energy of the electron in the ion field at a radius that is the ratio of the projectile velocity to the plasma frequency.

For ion velocities below the electron thermal velocity, a cloud of electrons shields the ion projectile. The energy exchange takes place as plasma electrons wander into the potential well created by the moving ion. Under these conditions the energy loss is

- Proportional to the square of the charge of the ion
- Proportional to the ratio of the ion velocity to the thermal velocity
- Proportional to the inverse of the square of the Debye length.

There is no logarithmic term in this instance and the energy loss is substantially smaller. This situation arises with energetic ions at high plasma temperatures or with ions that have lost their energy interacting with lower temperature plasmas.

The charge state of the ion projectile, as evident from the above discussion, is extraordinarily important in determining the stopping power in cold or plasma matter. The projectile charge depends on the balance of ionizing to electron capture collisions with electrons in the target, a balance described by rate equations.

In a plasma, the capture of a free electron by the ion is more difficult than capture of a bound electron in cold matter. Hence, the ionization state of an energetic ion in a plasma is higher than in cold matter. However, when ion velocities and electron thermal velocities in a plasma become comparable, the electron capture probability by an ion increases greatly. This may be the case for energetic ions projectiles in high temperature plasmas or for slower ions interacting with lower temperature plasmas.

Peter calculates the energy deposition in a plasma with a self consistent scheme where

- Energy dependent rate equations determine the ionic charge
- Ionic velocity and charge determine the energy decrement per unit path length
- Resultant energy determines the rate coefficients.

Peter presented results for the energy loss as a function of integrated path length that are quite similar to those of Nardi (1982). Both authors show that the initial energy deposition is about a factor of four higher in the

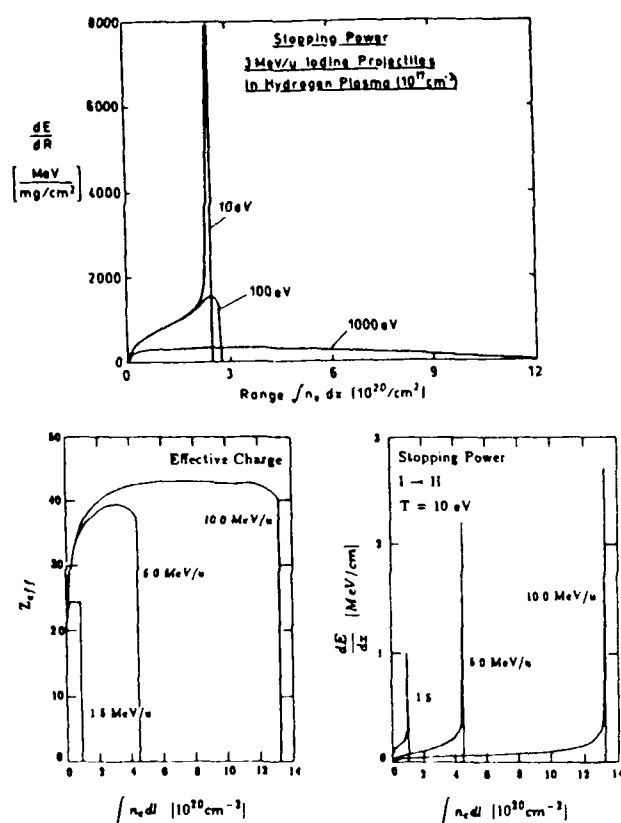
plasma than in a cold gas. The main contributing factors, as discussed above are

- A larger Coulomb logarithm in the plasma
- A higher charge of the ion projectile in the plasma.

The Bragg peak in Peter's calculations is sharper. The shape, from the foregoing discussion, is very sensitive to the ion velocity, the ratio of ion velocity to electron thermal velocity and the effective charge of the ion projectile. Ions that have lost a large fraction of their energy produce a narrow peak because a significant increase in the pre-factor of the energy loss results in an enhanced energy deposition. Slow electron recombination (high effective charge) also contribute to a sharp Bragg peak.

When ion velocities approach the electron thermal velocities, collisions with electrons are less effective at energy transfer and recombination becomes more likely. In this instance, the magnitude of the Bragg peak decreases as its shape broadens.

Some of Peter's results appear in Figure 2 which displays the energy loss the stopping power as a function of



a) The stopping power of hydrogen plasmas for several temperatures at a electron density of  $1.0 \times 10^{17} \text{ cm}^{-3}$ . The initial velocity of the  $\text{I}^+$  projectiles is  $11 \alpha_c$ , while at 10, 100, and 1000 eV the electron thermal velocity in the plasma is 0.86, 2.7, and 8.6  $\alpha_c$ , respectively.  $\alpha_c = 1/137$

b) Effective charge for  $\text{I}^+$  ions, H plasma, 10 eV,  $1.0 \times 10^{17} \text{ cm}^{-3}$ .

c) Stopping power for  $\text{I}^+$  ions, H plasma, 10 eV,  $1.0 \times 10^{17} \text{ cm}^{-3}$ .

Figure 2. Results of Ion-Stopping Calculations of Peter (1988).

range for several electron temperatures, the effective ion charge as a function of range for several initial energies and the stopping power as a function of range for several initial energies.

Professor Claude Deutsch, Laboratoire de Physique des Gaz et des Plasmas, U. Paris XI-Orsay, discussed a calculation of the ion energy loss by excitation of the bound target electrons. He treats these bound electrons as harmonic oscillators excited by binary encounters with ions at arbitrary impact parameters. Deutsch models the electrons around the projectile and target ions with an approximation where the electrons, even though in high orbitals, are still bound (melted atom approximation).

Deutsch's provisional conclusions are that an enhancement of stopping power at moderate electron velocities is likely to result from the finite charge distribution of the target and projectile. The calculation is stable as the impact parameter becomes large. Future calculations will look at high temperature plasmas.

Dr. Michail Basko, Institute for Theoretical and Experimental Physics, Moscow, also discussed the stopping of heavy ions in dense plasmas and the concerns for range lengthening at higher temperatures. As the temperature goes up, the number of bound electrons goes down as the number of free electrons increases which results, according to Basko, in an enhanced stopping power. However the encounters between the projectile and the energetic electrons are not as effective at energy transfer. This loss of effectiveness lengthens the range at high temperatures, an effect Peter described in his presentation as well. Basko (1983) also suggested in his lecture to use the mean square root of the minimum quantum mechanical and impact parameters in the logarithmic term of the stopping power.

## Interaction of Heavy Ions with Plasmas (experiments)

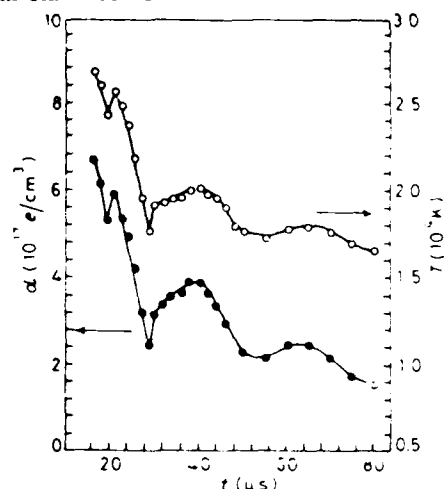
Several experiments are under way to test the ion stopping power theories. To eliminate the variable introduced by the degree of ionization of the target the target in some experiments is a fully ionized hydrogen plasma. The CNRS GREMI Laboratories, University of Orleans, France, developed the H target for two experiments, one at Orsay and one at GSI. This target is a 41 cm long B field stabilized plasma column with typical densities of a few times  $1.0 \times 10^{17} \text{ cm}^{-3}$  and temperatures of 1.4 eV at an ambient fill of 9 Torr of  $\text{H}_2$ .

Dr. Daniel Gardes, Institute of Nuclear Physics (IPN), Orsay, placed this plasma column in the beam line of the IPN accelerator and measured interactions with 2 MeV  $\text{amu}^{-1}$   $^{12}\text{C}^{4+}$  and  $^{32}\text{S}^{7+}$  (Gardes, 1988). Ms. Weyrich (1988), GSI, measured interactions with 1.4 MeV  $\text{amu}^{-1}$   $^{238}\text{U}$ ,  $^{84}\text{Kr}$  and  $^{40}\text{Ca}$  in the GSI UNILAC ex-

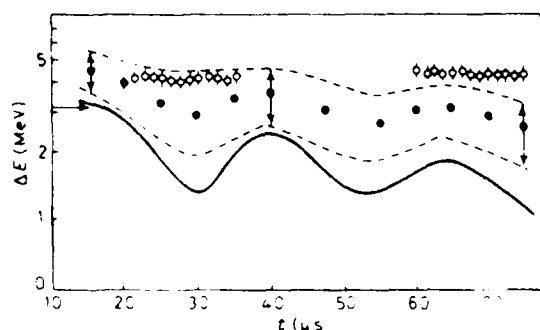
periment. Gardes determined the electron density  $n_e$  in the plasma by He-Ne laser interferometry and the electron temperature  $T_e$  by a two-wavelength absorption method. Weyrich used the Stark broadening of H $\beta$  for  $n_e$  and the intensity ratio of H $\beta$  to the continuum to determine  $T_e$ . The plasma properties measured at both laboratories coincide within the experimental error.

The energy loss in the plasma measured by Gardes scales as the square of the ion charge and shows a 1.5 fold enhancement over the energy loss in the cold gas. (See Figure 3) In Weyrich's experiment the energy losses show similar enhancements for Ca and Kr while for U the en-

other a self-consistent degree of ionization could be compared to experimental data. The uncertainty in the experimental data precluded such a comparison.



Evolution of the electron density (d) (●) and plasma temperature (T) (○) vs. time (t) for 13 kV discharge in 9 Torr H<sub>2</sub>.



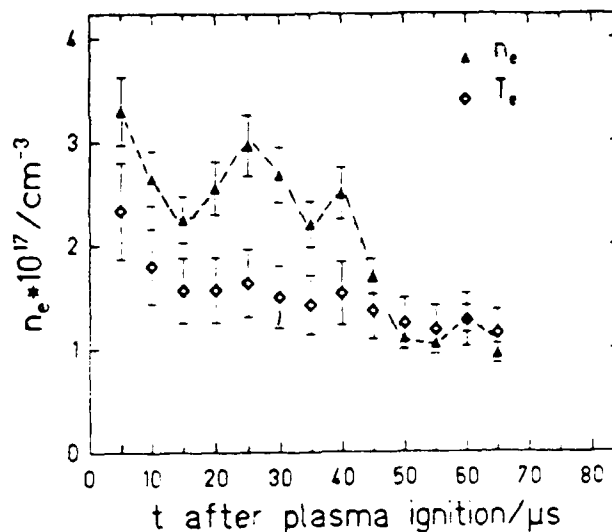
Experimental and calculated energy loss in plasma. The horizontal arrow indicates the energy loss of 3.11 MeV measured for the cold gas at a 9 Torr pressure. ○ experimental  $\Delta E$ , ● total  $\Delta E$  (calculated), — free  $e^-$   $\Delta E$  (calculated).

Figure 3. Electron density and ion energy loss in Hydrogen plasmas Gardes (1988) experiment (32 S 7+ ions, 2 MeV  $\text{amu}^{-1}$ ).

ergy loss has about a threefold enhancement. (See Figure 4) The experiment appears to confirm theoretical predictions of Nardi (1982) and Peter (1988) as discussed above.

Weyrich also attempted to determine if two sets of calculations of energy loss, one using a constant and the

### $n_e$ and $T_e$ of the Plasma



### $\Delta E$ Of $^{238}\text{U}$ -, $^{84}\text{Kr}$ - and $^{40}\text{Ca}$ -Ions

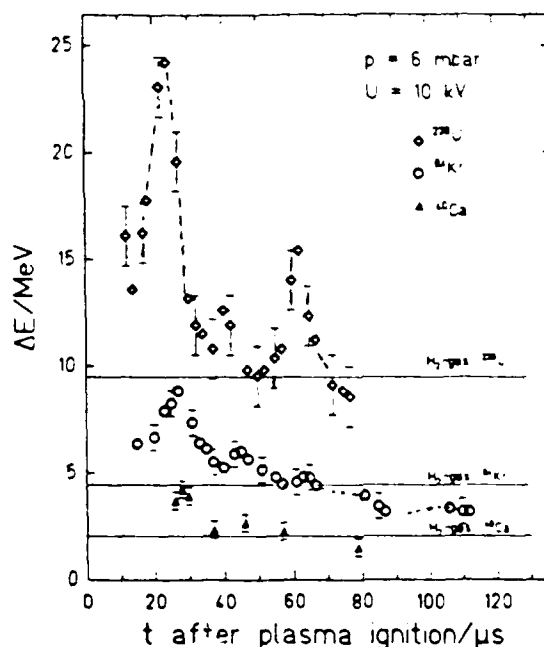


Figure 4. Electron density and ion energy loss in Hydrogen plasmas Weyrich (1988) experiment (1.4 MeV  $\text{amu}^{-1}$ ).

Both experiments encountered severe difficulties with fluctuations in transmission of the heavy ion beam originating with a lensing effect of the magnetic fields in the plasma. Gardes found a strong correlation between the transmitted ion current and the zeroes of the current in the discharge tube. He is evaluating an X-ray detection

scheme to determine the effective charge of the ion projectiles.

The above experiments demonstrated very clearly a larger energy deposition in plasmas than in cold gases. However, a more accurate comparison of theory with experiment requires plasma densities at least 1.5 orders of magnitude higher.

To produce these higher densities the FhG (Noll, 1988) built in Aachen, for installation at GSI, a very compact Z-pinch discharge apparatus. The choice of a pinch was considered superior to a plasma focus or a gas puff in terms of

- Attainable densities
- Column uniformity
- Raleigh Taylor instabilities
- Overlap of beam and plasma volume
- Zero magnetic field at the instant of the beam plasma interaction
- Reproducibility and reliability.

Dr. Reinhard Noll, FhG, discussed the technical challenges imposed by

- Packaging density of the apparatus (required to fit in the beam line)
- Electromagnetic compatibility (coexistence of nA detector and MA currents!)
- Reliability and reproducibility (300 firings are sometimes necessary to accumulate sufficient statistics).

The annular low inductance energy storage capacitor package and the Z-pinch are concentric. The Faraday cage topology surrounds the discharge system completely, taking advantage of inductive isolation. The capacitors deliver peak currents as high as 0.8 MA to the plasma with rates of rise of  $5.0\text{E} + 12 \text{ A s}^{-1}$  at charging voltages up to 70 KV while usual operating currents are 400 kA. The 20-cm-long annular column of plasma, pinches from an initial 7-cm to a 0.3-cm radius in about 1  $\mu\text{s}$  at velocities of a few times  $1.0\text{E} + 6 \text{ cm s}^{-1}$ . The pinch remains stable for at least 100 ns. With a prefill of 1.5 mbar electron densities of at least  $1.0\text{E} + 18 \text{ cm}^{-3}$  can be attained on axis over lengths of 20 cm.

Equally challenging were the on line optical diagnostics described by Dr. H. Kunze, FhG. A Mach-Zehnder interferometer measures on line, time integrated electron densities along the Z-pinch beam plasma interaction path. A streak camera detects the interference pattern which is a function of the electron density. A Pockels cell provides a synchronizing timing mark and an acousto-optic modulator shutter protects the photocathode of the streak camera from excessive exposure. During the collapse of the current sheet the fringe motion was too fast and at the time of the pinch the fringes disappeared.

Therefore fringes were only recorded as the plasma decayed. The online measurements agreed with the offline measurements taken with holographic interferometry at Aachen; i.e., an electron density of  $1.0\text{E} + 18 \text{ cm}^{-3}$  corresponding to full ionization of the target plasma.

Klaus Dietrich described the interactions of the beam with the target plasma. Beam transmission was lost at the time of peak electron density so energy loss was measured only during the decay phase. Dietrich measured a  $\Delta E$  of 15 MeV for 185 MeV  $^{132}\text{Xe}^{25+}$  with an areal electron density of  $2.0\text{E} + 19 \text{ cm}^{-2}$ .

The three Z-pinch experiments described so far lost transmission of the ion beam at the time of peak electron density. The audience at the meeting suggested severe deflection of the beam by plasma turbulence or trapped magnetic vortices as possible culprits for the beam loss. The issue of ion beam transmission loss is likely to remain open until better diagnostics for the plasma at the time of peak electron density are available.

## Interaction of Heavy Ions with Cold Matter (experiments and calculations)

Joachim Jacoby and Karin Mahrt presented preliminary results of two different target interaction experiments they are performing at GSI for their doctoral dissertation. These experiments differ from the hydrogen plasma experiments in the following

- Beam interaction region is a focal spot rather than a cylinder
- Target is a neutral gas rather than a plasma
- Targets are multi-electron atoms rather than hydrogen.

The ion source is the Maxilac RFQ preaccelerator (up to 4 mA of  $45 \text{ keV amu}^{-1} \text{ Ar}^{+}$  or  $\text{Kr}^{+}$ ). Magnetic and electrostatic quadrupoles focus the beam to a  $0.5\text{-mm}^2$  spot size. A kicker magnet system slices one or two 500- $\mu\text{s}$  macropulses that comprise about 6,000 10-ns wide ion micropulses produced by the accelerator.

The target in Jacoby's experiment is 1 Atm Xe gas contained in a 12 mm long, 6.5 mm diameter quartz tube sealed with  $80 \mu\text{g cm}^{-2}$  plastic foil beam windows. Jacoby measured  $4.0\text{E} + 16 \text{ cm}^{-3}$  electron densities through Stark broadening of the 467.1-nm Xe line and measured 0.8 eV electron temperatures using the line ratio technique. A charge coupled device (CCD) coupled Streak camera coupled with the spectrometer provides the time resolution. The temperature roughly agrees with the temperatures determined by observing the gas-dynamic rarefaction wave that originates in the beam-interaction region

The target in the experiment of Karin Mahrt is a gas puffed from a high speed valve. The gas-puff valve design achieved a tight seal and delivered reproducible puffs. The advantages of a gas-puff target, according to Mahrt, are

- Shorter experiment turnaround time (no foils to replace)
- No walls between the target and the observer
- Wider experimental parameter range.

Mahrt, using a streak camera-spectrometer combination as a diagnostic, is determining plasma properties such as the degree of ionization, plasma temperature, and beam energy coupling.

J. Maruhn, University of Frankfurt, described calculations of hydrodynamic flow in cold gas targets to complement the experiments of Mahrt and Jacoby. K. J. Lutz and V. Schneider, doctoral candidates under his direction, collaborated in this effort. Maruhn described calculations of the interaction of 45 MeV  $\text{amu}^{-1}$  Kr ions delivered as 10-ns micropulses at 70-ns intervals with 11-mm long, 6.5 mm diameter targets with densities ranging from  $1.0\text{E-}03$  to  $1.0\text{E-}02 \text{ g cm}^{-3}$  corresponding to pressures between 3 and 10 bar as well as Ar ( $1.0\text{E-}03 \text{ g cm}^{-3}$ , 1 bar).

The goal of Maruhn's calculations is to study beam propagation, shock formation, and expansion of the target column. Maruhn displayed profiles of the density and temperature at the center as a function of time and was able to follow shocks and rarefactions in  $1.0\text{E-}02 \text{ g cm}^{-3}$  Xe where the beam deposits 2 GW  $\text{gm}^{-1}$  in 3- $\mu\text{s}$  pulses.

The explicit Lagrangian solution, based upon the Los Alamos Conchas Spray code (LA 9294 MS) incorporates the SESAME equation of state, pressure iteration, and rezoning. The target undergoes axial expansion that drives an outward shock.

## Equations of State for Dense Plasmas

The EOS for a plasma at high energy density provides the pressure and internal energy of the plasma as a function of density and temperature. In general, HIF hydrodynamic calculations require the pressure and internal energy for matter at temperatures in the range of  $0 < T < 100 \text{ keV}$  and densities in the  $1.0\text{E-}04 < \rho \rho_0^{-1} < 1.0\text{E+}04$  range as a tabulated input.

In his lecture, Dr. Shalom Eliezer, Soreq Nuclear Research Center, Israel, reviewed EOS for dense matter (Eliezer, 1985). This subject will also be covered in a forthcoming course of the Enrico Fermi International Physics School (1989) under Eliezer's direction.

Zeldovich (1967), in a chapter on the thermodynamic properties of solids at high pressures and temperatures, discusses some of the physical background necessary to

understand the contributions to the pressure and the internal energy of

- Electrons at zero temperature
- Thermal excitation of the electrons
- Ionic thermal excitations.

Eliezer (1985) examines these contributions in more detail and displays, as an example, pressure and internal energy as a function of compression with a family of curves--isotherms--where the temperature is a parameter. Details about the EOS at high densities based upon the Thomas Fermi model can be found in the review by Ghatikar (1984), written in collaboration with Eliezer, and in More (1988).

Dr. Susan Pfalzner, Institute for Applied Physics, Technical University, Darmstadt, discussed the ionization degree of classical and dense plasmas. Some of Pfalzner's presentation, based upon her recent doctoral dissertation, appears in recent conference proceedings (Pfalzner, 1988, 1988a).

The ionization degree in a plasma, according to Pfalzner determines

- Free electron density
- Plasma pressure
- Electron thermal conductivity
- Electrical conductivity
- Bremsstrahlung emission
- Photoelectronic recombination.

Pfalzner began her lecture by introducing the ion coupling parameter or correlation parameter GAMMA (More, 1988) expressed as the ratio of the ion-ion electrostatic energy calculated at one ion radius to a thermal kinetic energy ( $= kT$ ). In classical matter,  $\text{GAMMA} < 1$  (ions are decoupled from each other), the ionization degree depends on the Saha equilibrium. In dense matter,  $\text{GAMMA} > 1$  (ions coupled to each other) the fields from neighboring ions merge. Free electrons, forced into the ion core (More, 1988), screen the bound electrons inducing a process equivalent to pressure ionization.

A second equally important parameter describing dense matter is the Fermi degeneracy parameter THETA: the ratio of the electron thermal energy to the Fermi limiting energy (Shepherd et al., 1988). For HIF plasmas, high electron densities will yield THETA much less than one.

Highly compressed HIF plasmas become strongly coupled ( $\text{GAMMA} > 1$ ) and Fermi degenerate ( $\text{THETA} < 1$ ) when interionic distances get small and electron densities become large. The calculation of the ionization degree for these plasmas involves (Shepherd et al., 1988; Meyer-ter-Vehn et al., 1988) formulation of a potential function and performing a self consistent par-

tial wave analysis that yields the density of states for the electrons. The ionization can then be obtained from the density of states. For strongly coupled, Fermi degenerate plasmas the Thomas-Fermi-Dirac model for the potential (that includes the exchange interaction) is a reasonable choice of potential for the lower temperatures. However, the choice of potential is only one aspect of the calculation. The other aspect are the approximations that yield the correct atomic structure and continuum levels. Meyer-ter-Vehn et al. (1988) elaborates these ideas in some detail for cold compression of metals.

### Spectroscopic Diagnostics of Dense Plasmas

Professor Claude Deutsch, Orsay, and Professor Yitzhak Maron, Weizmann Institute, Israel, gave overviews on spectroscopic diagnostics methods for dense plasmas. Deutsch's background lecture looked at spectroscopy as the only tool available to measure electron densities in the  $1.0\text{E}+14 < n_e < 1.0\text{E}+16 \text{ cm}^{-3}$  and electron temperatures in the range  $0.5 < T_e < 1.0\text{E}+04 \text{ eV}$ . In these regimes, the densities are too high for microwave interferometry, laser holography, and Thomson scattering.

Interpretation of spectroscopic measurements requires a calculation of the effects of electron impacts on line emission from ions. Electron impact produces electric fields in the neighborhood of the ions and perturbs their energy levels. Correlated electric fields, which are slow compared to electron lifetimes in the excited states, result from electrons contained in the Debye sphere. The quantum mechanical calculations of the energy levels of thermal ions incorporate these electric fields as a perturbation yielding the width as well as the shift of the spectral lines. Measurements of widths and shifts of isolated lines allow the test of the theory against experiment. In most instances, it is possible to relate the shift and full half width of the spectral line to the electron density and charge state of the ions.

Maron (Maron et al., 1988) described the methods used by his group to understand the physical processes that take place in the anode plasmas of ion diodes. The purpose of his work is to develop new diagnostic tools and plasma models that can be applied to plasmas in pulsed power devices such as the Z-pinch plasmas used for heavy-ion-target interaction studies.

To obtain the understanding, Maron described the very effective combination of careful spectroscopic measurements and numerical modeling that consists of

- Reliable acquisition of high resolution and accurate data
- Construction of a theoretical framework for analysis of the data

- Construction of models that incorporate the data to understand highly dynamic nonequilibrium plasmas.

Using these methods, his group has

- Measured velocity distributions of ions and neutrals
- Determined electron temperatures
- Determined absolute fluxes of ions from the dielectric substrate
- Measured time resolved magnetic fields in the plasma
- Formulated a theory that accounts for anomalous conductivity of the plasma
- Applied a laser-induced fluorescence technique to measure particle density and velocity distributions
- Studied the role of neutrals in the expansion of the anode plasma
- Studied the ionization instability and magnetic insulation breakdown in ion diodes.
- Determined turbulent electric fields from Stark broadening and plasma satellites
- Observed non-Maxwellian electron energy distributions from time-dependent level population ratios.

Maron suggested that the same methods could be very useful in the study of the z-pinch targets used in heavy ion stopping experiments. Detailed knowledge of the properties of these plasmas at the time of maximum compression are required to the understanding particle losses and particle stopping powers observed in experiments.

### Interaction of Heavy-Ion Beams with Matter (proposed experiments and calculations)

Dr. N. Tahir, ABAS Corporation, Karlsruhe, performed calculations to survey possible SIS experiments that would experimentally confirm the entries in the SESAME opacity tables. The experiments Tahir proposes are described at the end of the radiation transport section of this report.

As part of a lecture on radiation hydrodynamics, Dr. Jurgen Meyer-ter-Vehn, MPQ, reiterated his viewpoint that, the indirect drive concept, in which the ion beam energy is thermalized into soft X-rays is a realistic approach that circumvents the asymmetries resulting from energy deposition from several ion sources, in the outer layers of the of the target. For indirect drive targets, the main ion issues become

- Efficient conversion of ion beam energy into thermal X-rays (work in collaboration with Masakatsu Murakami of ILE)
- Implementation of small converter volumes of arbitrary shape.

Physics, common to other indirect drive approaches, decouple from the ion-converter interaction physics

- Radiation confinement in the cavity
- Radiation-driven implosions (Doctoral work by Norbert Kaiser).

Meyer-ter-Vehn elaborates upon some of these issues in a recent conference presentation (Meyer-ter-Vehn, 1988b).

## Radiation Transport and Conversion in Dense Plasmas (computations and theory)

Professor Gerald Pomraning, UCLA, discussed the discretization of the equation of radiative transport through finite element methods. These methods have become increasingly popular in recent times for the solution of neutron and gamma ray transport as well.

For pedagogical reasons, Pomraning chose to demonstrate the approach with the one group (grey) radiation problem that neglects hydrodynamics. Choosing  $T^4$  as the variable and nondimensionalizing the equation he obtains a first order partial differential equation for the radiation flux in space and time variables. First order time differencing on the equation yields a first order differential equation, in the space variables, for conservation of the radiation flux.

The problem space is then divided into spatial zones. The flux conservation equation must then be solved, over the whole problem space, at each time step, by-passing the nonlinearities by using the temperature from the last time step. The solution of this equation is known as the power iteration in neutronics or the lambda iteration in astrophysics.

Pomraning then described the solution strategies for this equation:

- Step (upwind) differencing assumes the value of the outgoing flux is equal to the average value in the zone
- Diamond differencing assumes the average of the flux in the zone to be equal to the average of the incoming and outgoing fluxes
- Linear discontinuous finite element differencing assumes the flux is a linear function of position in the zone, allowing discontinuities at zone boundaries
- Modified linear discontinuous method incorporates an odd weighing function for the flux as a function of position. In special cases, this function returns the flux distribution of the other methods.

According to Pomraning, the last method, applicable to curvilinear and multidimensional geometries, yields the correct diffusion limit. At present, it is the best method to solve neutron, gamma-ray, and radiation transport problems. Pomraning recommends Larsen et al.

(1987, 1989) as a reference for more details on these methods.

In another lecture on radiation transport, Dr. Willi Hobel, KfK, described the multigroup radiation diffusion code MULRAD, a part of KATACO, the Karlsruhe target code. KATACO calculates light-ion-beam--target interactions as part of the KfK LIF program (Bauer et al., 1988). The modular structure of KATACO incorporates

- MULRAD-a radiation transport code
- MEDUSA-a two-temperature Lagrangian plasma hydrodynamics code
- EDEPOS-an ion energy deposition code
- CIRCE-a charge particle transport code
- TIMEX-a neutron transport code
- EOS-TAB-a tabular equation of state.

As described by Hobel, MULRAD solves the energy equations for photons ions and electrons, while MEDUSA (Christiansen et al., 1974; Tahir, 1986) solves the mass and momentum conservation equations. MULRAD neglects photon scattering, and treats the radiation transport in the diffusion approximation assuming that the photon emission source is given by the Planck function (local thermodynamic equilibrium--LTE--approximation).

Upwind differencing, as described by Pomraning, discretizes the equations in the space coordinate. The time discretization integrates the functions associated with the radiation field taking the value at the present time step (full implicit) to predict the value for the next time step. The electron and ion properties for the next time step are obtained by taking half the value at the present time step and half the value from the previous time step (half-implicit and half-explicit).

To smooth the nonlinearities arising from the fourth power of the temperature, the cube power of the temperature at the previous time step times the temperature at the present time step determines the radiation flux at the next time step.

MULRAD takes the temperatures and densities at the previous time step to interpolate the opacities from a 33-frequency group library based on the SESAME tables. MULRAD can treat up to 20 different materials separately.

The code is operational and Hobel displayed preliminary results of benchmark calculations that compare results with the Alcouffe problem. MULRAD's temperature profiles obtained compare favorably with temperature results from the Alcouffe classical benchmark calculation. A comparison of temperature profiles calculated by MEDUSA with profiles from the NRL code (Goel et al., 1987) is also very favorable. Streamlining, improved treatment for the boundary conditions and additional verifications will improve confidence in the code.



Hobel concluded his presentation by comparing the features of the MULRAD and MULTI (Rambis et al., 1988) codes. See Table 1.

**Table 1. MULRAD-MULTI Comparison**

MULRAD	MULTI
Multi-group diffusion theory	Multi-group transport theory
Plane, cylindrical, or spherical geometry	Plane geometry
No photon scattering	No photon scattering
LTE	LTE and non-LTE
Radiation time derivative accounted for	Neglect radiation time derivative
Lagrangian hydrodynamics	Lagrangian hydrodynamics
Separate energy equations for ions and electrons	One-energy equation
No momentum coupling between matter and radiation fields	No momentum coupling
Crank-Nicholson time integration scheme	Time-splitting integration method
Implicit integration for radiation energy	
Explicit integration of momentum equation	

Dr. Jurgen Meyer-ter-Vehn, MPQ, discussed self-similar solutions of the 1-D hydrodynamical calculations with radiative heat conduction (Reinecke et al., 1988). He described the invariance of the equations with respect to infinitesimal generators. He then showed how a scale transformation generator leads to Lie invariants that turn the hydrodynamic partial differential equation into a system of ordinary differential equations. Infinitesimal generators then transform these solutions into new solutions of some interest.

One analytical solution to the equations yields the classical Kidder implosion solution in the limit of no heat conduction. Infinitesimal generators operating on this solution produce the *birth and death* solution for a point explosion. In this solution, material starts at the origin, expands, reaches zero velocity over the whole flow field, turns around, and implodes. The zero velocity stage of the solution, which fits the initial conditions for a pellet implosion, is of interest for HIF.

As a different example, Meyer-ter-Vehn presented the solution associated with a sudden energy release--point explosion--in an ambient gas. In this solution, a critical parameter controls whether the problem is hydro or heat wave dominated. In the hydrodynamics-only solution (no heat conduction), the explosion drives a shock in the ambient medium. In the heat conduction-only solution (no hydrodynamics), an isochoric heat front propagates into the medium with a smaller velocity than the shock front in the hydrodynamics-only case.

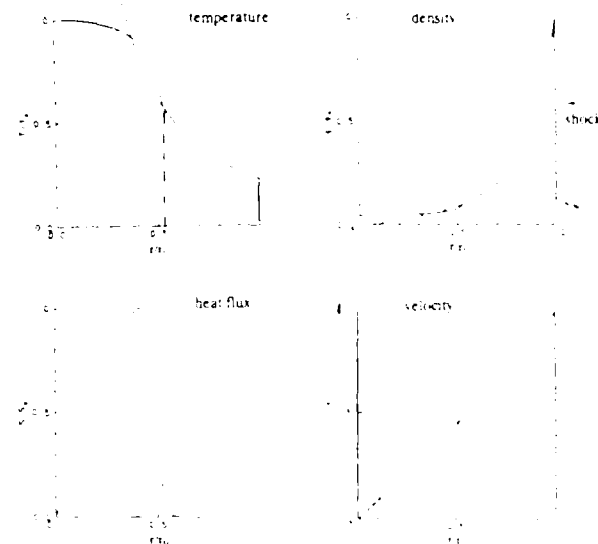
When both hydrodynamics and heat conduction are present, whichever is dominant determines the physics. When hydrodynamics is dominant (weak heat conduction) the shock runs ahead of the heat front. Heat transport behind the heat front, away from the center,

- Cools the core of the explosion
- Sustains a high density behind the heat front
- Has a small effect on the velocity field.

In the strong heat conduction case, the situation is altogether different

- Heat front propagates ahead of the shock
- Shock is almost isothermal
- Heat flux behind the shock drops dramatically
- Density peaks immediately behind the shock
- Velocity rises sharply across the shock
- Both density and velocity drop to zero between the shock and the center.

The results appear schematically in Figure 5 (weak heat conduction) and in Figure 6 (strong heat conduction). The figures display profiles of density, velocity, temperature, and heat flux for both cases.



**Figure 5.** Results of similarity calculations with weak heat conduction (Reinecke, 1988).

Dr. N. Tahir, ABAS Corporation, Karlsruhe, performed calculations to survey possible SIS experiments that would experimentally confirm the entries in the SESAME opacity tables. Tabular opacities are an ingredient in the calculations of radiation transport and conversion of heavy ion energy into thermal radiation. According to Tahir, the atomic models and calculation methods that generated the SESAME table entries are not given; and even if they were available, the atomic physics of heavy elements is so complicated that the data deserve experimental confirmation.

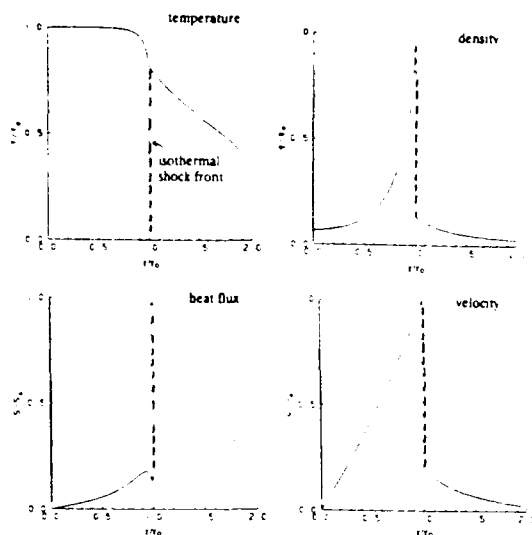


Figure 6. Results of similar calculations with strong heat conduction (Reincke, 1988).

Tahir performed the calculations with the MEDUSA-KAT hydrocode (Tahir et al., 1988). By assuming complete thermodynamic equilibrium between the radiation field and the electrons, the energy density, specific heat, pressure, and thermal conductivity of the radiation field become simple functions of the electron temperature.

The Xe target used as an example is a 200- $\mu\text{m}$ -radius 1 cm-long cylinder, and the beam, with a 100- $\mu\text{m}$ -radius, deposits  $10 \text{ TW g}^{-1}$  (constant specific energy deposition power) in 40 or 100 ns. Target densities range between  $1.0\text{E-}04$  and  $1.0\text{E-}01 \text{ g cm}^{-3}$  allowing calculations for optically thin as well as optically thick conditions.

Tahir's calculations reveal a subtle interplay between target temperature, density, dimensions, optical thickness, radiation conductivity, and electron heat conductivity. This interplay determines the balance of emission and absorption in different parts of the target. Calculations with initial densities of  $1.0\text{E-}03 \text{ g cm}^{-3}$  display this subtle interplay. Without radiation conduction, the hot beam interaction region drives a shock into the colder region. This shock reflects as a rarefaction at the cold gas interface.

In Tahir's sample calculation, the radiation heat conductivity is higher than the electronic heat conductivity and the optical thickness of the material surrounding the target is larger than the material in the target. Hence, radiation conduction transfers energy very effectively from the center to the outer portions of the target reducing the temperature of the interaction region and increasing the temperature of the outside region.

## Conversion of Beam Energy into X-ray (theory)

Dr. Masakatsu Murakami, visiting MPO from the Institute for Laser Engineering, Osaka, Japan, provided, from his vantage point, an overview of the critical issues that affect indirect drive HIF

- Conversion efficiency of ion energy to soft X-rays in polyurethane foam
- Confinement of black body radiation in the cavity
- Coupling of the radiation to the outer layers of the pellet.

The emphasis of Murakami's lecture was on the conversion of ion energy to soft X-rays. He described approximate calculations for energy conversion in a cylindrical converter that attains a stationary power balance (per unit length) between

- Power deposited by the ion beam (with a constant specific power deposition in  $\text{W g}^{-1}$ , proportional to the density and cross sectional area of the converter)
- Power dissipated in hydrodynamic expansion (proportional to the surface area of the cylinder, the cube of the sound speed and the density)
- Power dissipated by black body radiation (proportional to the surface area of the cylinder, the Stefan-Boltzmann constant, an opacity factor, related to the optical thickness, and the fourth power of the temperature).

Murakami obtains the optical thickness from

- Power law approximation to the Rosseland mean free path (proportional to the fourth power of the temperature and the inverse of the square of the density)
- Temperature profile approximated from calculations on plane surfaces (Meyer-ter-Vehn et al., 1985).

Murakami used the following parameters:

- 10 ns pulses
- $1.0\text{E+}15 < P < 1.0\text{E+}18 \text{ W g}^{-1}$
- $r_0 = 0.1 \text{ cm}$ ,  $\rho_0 = 0.1 \text{ g cm}^{-3}$
- $c_s = [(\gamma - 1)c]^{1/2}$ ,  $\gamma = 1.5$ ,  $c = 4.0\text{E+}11 [T/\text{eV}]^{1.2} (\text{erg g}^{-1})$ .

Murakami's results appear in Figure 7. He determined an optimum specific power deposition  $P$  of about  $5.0\text{E+}16 \text{ W g}^{-1}$  that provides a conversion efficiency of 0.8. When the power is lower than this optimum, the converter expands before it can heat up. Above the optimum power, the temperature becomes too high, the optical thickness drops, and the radiation escapes from the con-

verter. More details about these calculations appear in Murakami et al. (1988) and Meyer-ter-Vehn (1988b).

Energy conversion of a laser pulse into X-rays was also the underlying theme of Meyer-ter-Vehn's presentation. He discussed very recent results of MPQ calculation of the radiation hydrodynamics of laser-irradiated gold foils. The parameters used in these MULTI3 code (Ramis, 1988) calculations are:

- Planar geometry and normal incidence ( $1.0E + 14 \text{ W cm}^{-2}$  @ 350 nm)
- Electronic heat flux inhibition factor equal 0.08
- Inverse bremsstrahlung light absorption
- Light reflection at critical surface
- 100 cells on irradiated side of the target
- 50 cells in back of target
- 500 ps runs (50 ps) rise-time and 5ns runs (500 ps risetime)
- SESAME EOS
- Non-LTE ionization (Klaus Eidmann, MPQ)
- Non-LTE opacities (Klaus Eidmann, MPQ) with 20 frequency groups (SNOP Code).

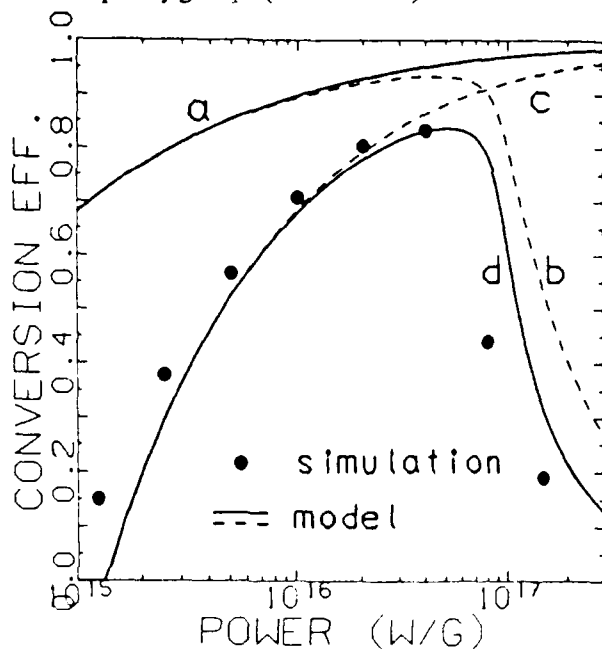


Figure 7. Conversion efficiency of ion beam energy into soft X-ray radiation (Murakami, 1988).

Meyer-ter-Vehn began his presentation by displaying EOS tabular data as a three dimensional surface of

- Pressure-temperature-density (Pressure EOS)

- Specific energy-temperature-density (Specific Energy EOS)
- Ionization state-temperature-density (Ionization EOS)
- Opacity-temperature-density.

Since these surface plots complement previous discussions of EOS, ionization, and opacities, I find it worthwhile to review some of Meyer-ter-Vehn's comments.

**Pressure (Figure 8a).** Surface reveals a negative pressure (tension) region arising at low temperatures and densities below solid density. A very steep pressure rise accompanies compression at room temperature. The

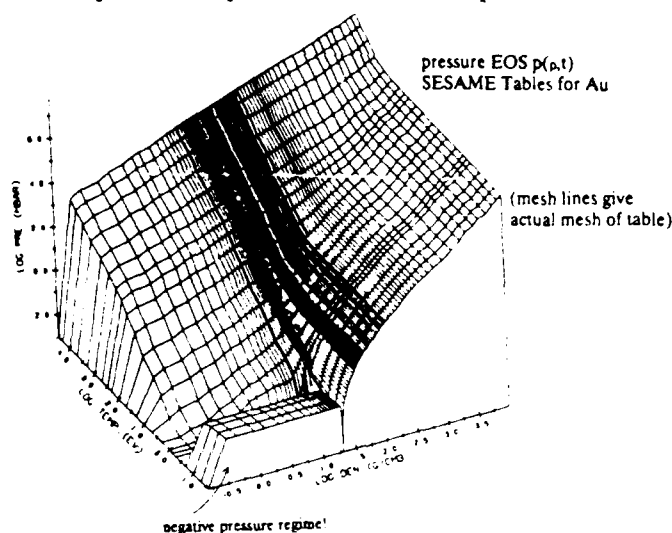


Figure 8a. SESAME Au pressure EOS for MPQ-ILE benchmark calculations.

pressure becomes a much gentler function of temperature and density above 10 eV and above solid densities.

**Specific energy (Figure 8b).** Surface shares many of the features of the pressure surface, except for the nega-

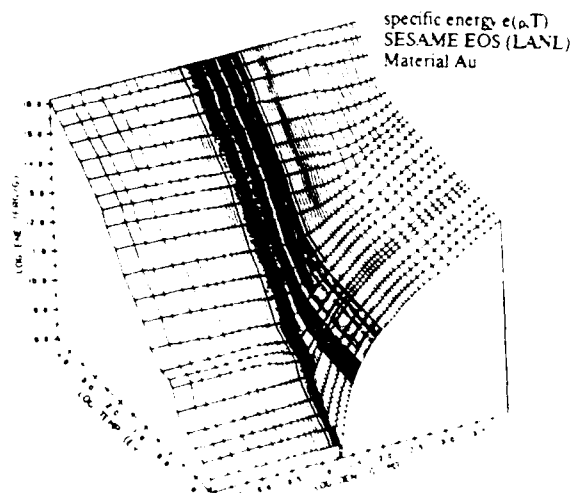


Figure 8b. SESAME Au specific energy EOS for MPQ-ILE benchmark calculations.

tive region discussed above. It displays some step-wise features at 10 eV and about 1 keV.

**Ionization state** (Figure 9). Surface rises in steps as temperature increases. Step features are pretty independent of density for a fixed temperature. Steps probably result from ionization of successive shells.

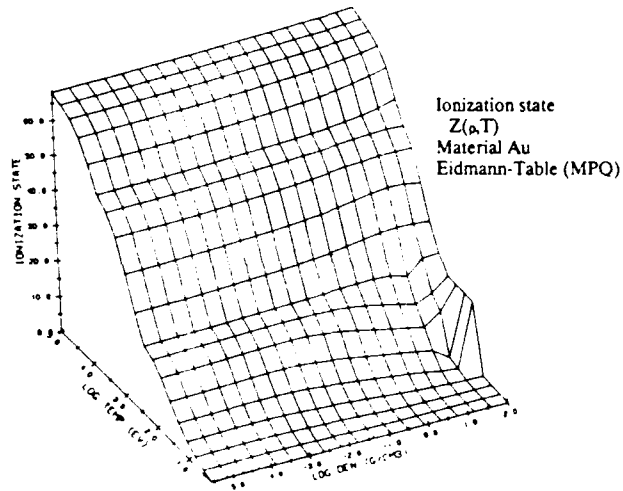


Figure 9. Ionization state calculation for Au. (Eidmann table, MPQ)

**Opacities** (Figures 10a and 10b). The opacity surfaces display large changes at approximately the same temperatures as the energies describing the photon group; i.e., the

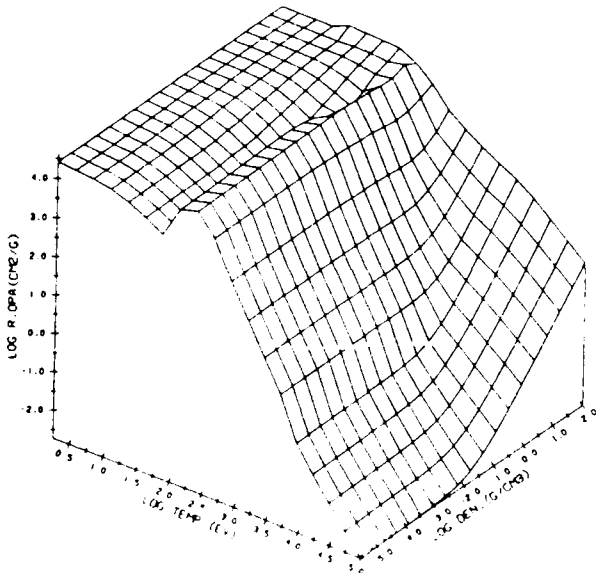


Figure 10a. Au opacity (400-500-keV group) for MPQ-ILF benchmark calculations.

2.4 - 2.6-keV group opacity drops very sharply for temperatures above 3 keV. Some of these features coincide with the features of the ionization surface.

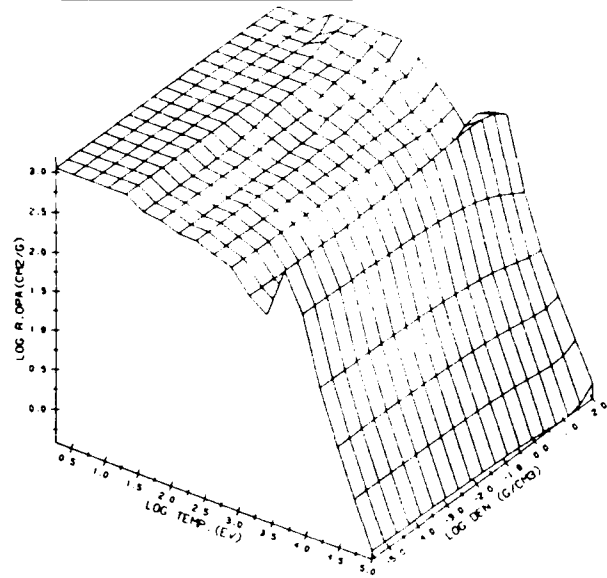


Figure 10b. Au opacity (2.4-2.6 keV group) for MPQ-ILF benchmark calculations.

Meyer-ter-Vehn also displayed results of the hydrodynamic calculation for the 500-ps and 5-ns exposure. Plots are in the form of surfaces of the variable as a function of time and mass coordinate.

### Summary of results for the 500-ps calculations

**Pressure** (Figure 11a). Reaches 10 Mbar at the absorption layer. Shock increases pressure inside the foil to comparable levels.

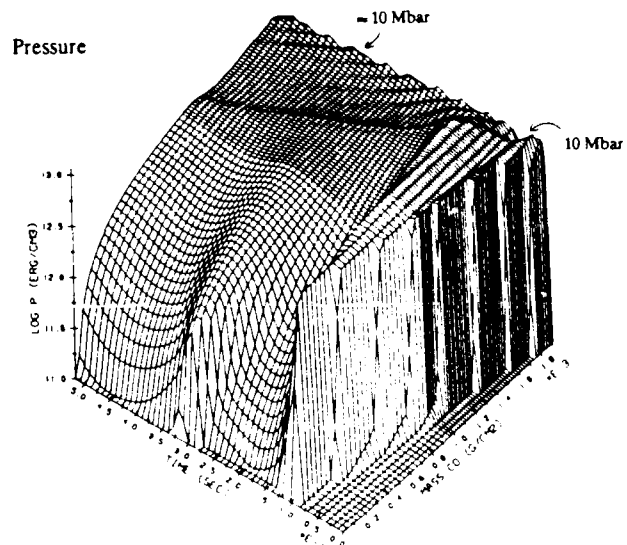


Figure 11a. Pressure from MPQ-ILF benchmark calculations (500-ps, 0.35-um laser pulse).

**Density** (Figure 11b). Initial shock compression causes a large spike. Otherwise, outside the absorption layer density remains pretty close to solid densities.

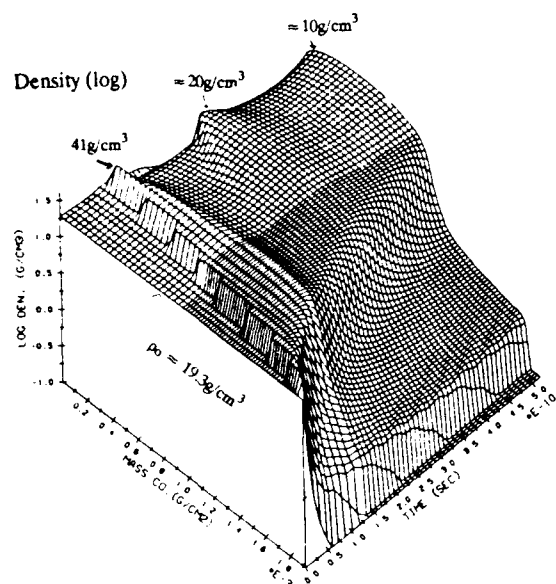


Figure 11b. Density from MPQ-ILE benchmark calculations.

**Temperature** (Figure 12a). The absorption layer gets to 1.7 keV. A hydrodynamic shock propagates to the interior of the foil rising the temperature to about 10 eV. The heating wave follows more slowly rising the temperature to 100 eV.

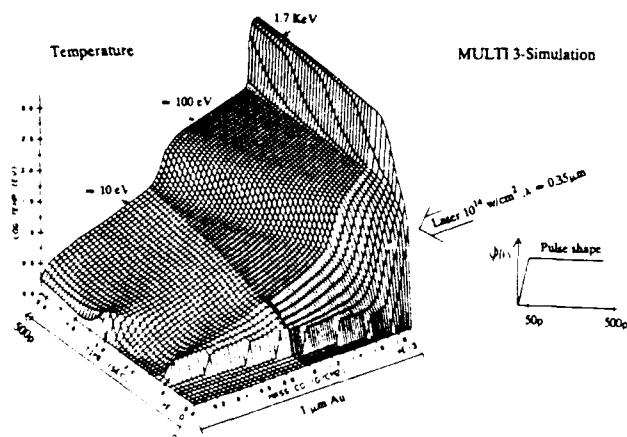


Figure 12a. Temperature from MPQ-ILE benchmark calculations.

**Ionization** (Figure 12b). Rises with the temperature wave to +10 or so and jumps to +49 in the laser absorption region.

**Radiated flux** (Figure 13). Displays a very strong peak associated with the high temperatures attained by the absorption layer. Propagation of the X-ray flux into the material is very evident. X-ray flux comprises 43 percent of incident laser energy flux.

In this short summary, it is impossible to do justice to the beauty of the physics contained in these plots. Hours could be spent exploring the nuances of the radiation and hydrodynamic fields. I include them in this report to

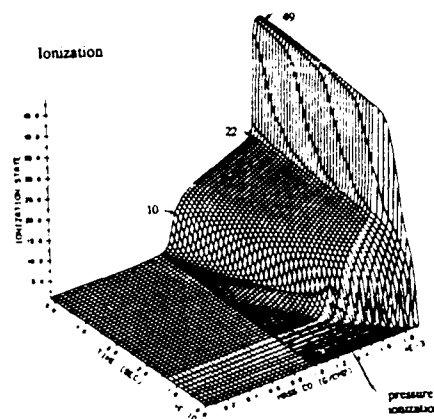


Figure 12b. Ionization from MPQ-ILE benchmark calculations.

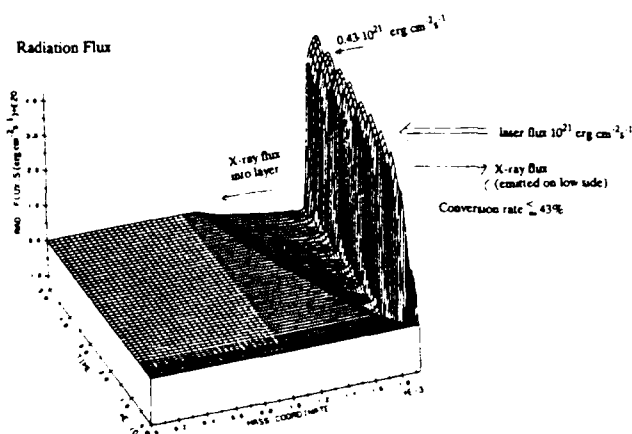


Figure 13. Radiation flux from MPQ-ILE benchmark calculations.

share the excitement of the audience during Meyer-ter-Vehn's presentation

## Conversion of Beam Energy into X-rays (experiments)

Dr. Klaus Eidmann, MPQ, in a companion presentation, described experiments to explore the conversion of laser light into X-rays in a regime where the input power ranges from  $1.0E+10$  to  $1.0E+16$  W cm<sup>-2</sup>, pulse durations range from fs to ns, and wavelengths range from 0.1 to 10 μm. The converters are plasmas with keV temperatures, densities in the  $1.0E+19$  to  $1.0E+23$  cm<sup>-3</sup> range and 10 Mbar pressures. In this regime, plasmas convert laser light into X-rays very efficiently. Eidmann emphasized the importance of distinguishing two plasma regions in the conversion process in high-Z materials (Sigel et al., 1988). Thermal electrons in the conversion layer ( $T_e \sim 1$  keV,  $1.0E-01$  g cm<sup>-3</sup>) partially absorb the laser light and

radiate X-rays. To model the absorption region, Eidmann uses the steady state approximation (emission and absorption coefficients depend on temperature and density only) and includes some non-LTE effects at the lower densities. Eidmann (1988) describes the atomic model for these calculations in detail, including the energy levels, ionization states, and emission and absorption coefficients.

A fraction of the X-ray radiation produced in the conversion zone flows outward through the optically thin, non-LTE plasma. Another part flows inward, depositing energy in the cold wall and generating an ablative type heat wave. The heated material re-emits X-rays and this re-emitted radiation, flowing in the outward direction, according to Eidmann is important in establishing the overall energy balance as well as determining the X-ray spectrum observable from the interaction. Results of the detailed calculations will appear in two forthcoming papers by Sigel et al., (1989?) and Eidmann et al., (1989?).

The experiments at MPQ have three target arrangements--cavities, thick foils, and thin foils. In the first arrangement, laser energy focused into a cavity produces Plank black body radiation. Several publications from MPQ and ILE describe these experiments, part of the MPQ-ILE collaboration.

The second arrangement, described by Eidmann in more detail, involves the conversion of light in thin targets to diagnose the X-ray conversion and emission processes. The iodine lasers driving the foils are Asterix III that delivers 100 J of 1.3  $\mu\text{m}$  and 0.44- $\mu\text{m}$  radiation in 300 ps and Asterix IV that delivers 2 kJ in 1 ns. A Nd laser at 0.53  $\mu\text{m}$  is also available in two modes: 10 J in 3 ns and 0.3 J in 30 ps. At  $1.0\text{E} + 14 \text{ W cm}^{-2}$ , with a 0.53  $\mu\text{m}$ , 3 ns pulse Eidmann has measured conversion efficiencies as high as 60 percent for Au, 35 percent for Cu, and about 8 percent for Al. At this wavelength, 30-ps pulses have a much lower conversion efficiency, typically 10 to 20 percent for the same materials. For Au, short wavelengths (0.44  $\mu\text{m}$ , 0.3 ns pulses) produce peak conversion efficiencies of 0.6 at  $1.0\text{E} + 13 \text{ W cm}^{-2}$  of 0.44- $\mu\text{m}$  radiation while the energy conversion efficiency at 1.3  $\mu\text{m}$  is lower by a factor of 2 at the same power densities. The shorter wavelengths are more efficient because the laser energy is absorbed deeper in the plasma. The energy conversion decreases with intensity because energy transport through electron conduction starts overtaking radiation transport at the higher power densities.

The third arrangement, thin foils, is applicable to

- X-ray-driven foil acceleration (X-ray-produced plasma)
- Opacity studies
- Pumping of X-ray lasers
- Windows for indirect drive cavities

#### ● Targets for heavy ion stopping.

The simulations show that a 3-ns, 0.53- $\mu\text{m}$   $1.0\text{E} + 12 \text{ W cm}^{-2}$  pulse is almost completely absorbed once the Au foil thickness reaches 75 nm and the conversion efficiency measured at the front of the foil keeps increasing reaching about 0.6 at a thickness of 120 nm while measured at the rear peaks at 0.30 at a foil thickness of 40 nm.

An experiment to test the thin foil simulations is currently under way. The 3-ns laser pulse with intensities of  $1.0\text{E} + 13 - 1.0\text{E} + 14 \text{ W cm}^{-2}$  strikes a 500-2000 Å-thick gold layer deposited on a 1- $\mu\text{m}$  thick polypropylene substrate. Preliminary measurements show good conversion efficiencies over a range of thicknesses and a measurable delay in the onset of X-ray radiation at the back of the foil.

Eidmann considers two types of target to stop a 3-ns pulse of 10 J of heavy ions with a focal spot of 700  $\mu\text{m}$  ( $1.0\text{E} + 12 \text{ W cm}^{-2}$ ):

- A 1- $\mu\text{m}$  polypropylene substrate with a  $Z_{\text{ave}} = 3$  at  $T = 20 \text{ eV}$ , a density of  $1 \text{ g cm}^{-3}$  and an areal electron density of  $2.0\text{E} + 19 \text{ cm}^{-2}$
- A 0.2- $\mu\text{m}$  Au foil with a  $Z_{\text{ave}} = 15$  at a  $T = 30 \text{ eV}$  with a density ranging from  $0.1 \text{ g cm}^{-3}$  to  $1 \text{ g cm}^{-3}$ .

The lifetime of these foils could be about 10 ns before undergoing hydrodynamic disintegration.

### Laser Pumping by Heavy Ion Beams

As part of a lecture devoted to radiation hydrodynamics, Meyer-ter-Vehn discussed some of the difficulties involved in the implementation of X-ray lasers driven by heavy ion beams by emphasizing

- Importance of the stopping processes of heavy ions in matter
- Nonequilibrium nature of the beam-plasma system
- Importance of choosing the "right" geometry
- Insights required on the level dynamics (Kancher, 1989) concerning degrees of ionization, rate equations, population levels, and emission spectrum.

Andreas Ulrich, Physics Department, Technical University, Munich, discussed laser pumping by heavy ion beams. In a systematic approach, Ulrich's measured the spontaneous emission from pure rare gases (Ne, Ar, Kr, Xe) excited by short, high-energy, ion-beam pulses (2 ns, 100 MeV, 32 S 9+, 20 kHz) delivered by the Munich Tandem Van der Graaf accelerator. Ulrich detected light emission perpendicular to the 30 cm-long, 200-mbar Ar-target by coupling the spectroscope to the target through a mirror.

In a first set of experiments Ulrich measured line intensities by gating a pulse height analyzer soon after the ion beam interaction. This technique allowed him to

measure line intensities as the beam excites the Ne gas, which takes place in a time-scale of about 5 ns, and as the excitation decays in a scale of 20 ns.

By detecting photons from a known volume, knowing the solid angle, folding the spectrometer sensitivity, assuming the medium is optically thin, and knowing the transition probabilities, Ulrich obtained the population densities for the excited levels.

He also showed that by measuring the decaying intensity of a spectral line as a function of time for several pressures, he can calculate the kinetics of the level population. He found that for the Ne II 337.83-nm line, the rate coefficient for collisional depopulation increases linearly with pressure.

Ulrich's future plans include measuring the rise-times of population levels, measuring the gain in a cavity collinear with the beam, measuring the spatial distribution of the excitation, and measuring the excitation in a solid Xe target with the beam of the RFQ accelerator (at GSI with R. W. Muller).

Dr. Boris Chichkov, a visitor at MPQ from the Theoretical and Experimental Physics Institute in Moscow, lectured on the application of Z-pinch plasmas as the active medium for X-ray lasers. He reviewed two avenues to the production of an X-ray lasing plasma. One avenue is collisional excitation by electrons of plasmas produced with optical lasers, that populates the upper levels (Matthews et al., 1988). The other is the use of Z-pinch plasma experiments that offer the possibility of producing several joules of X-rays with a reasonable efficiency from the wall socket.

Chichkov began by discussing the electron density regimes required for X-ray lasing plasmas concluding that Z-pinch plasmas have insufficient electron densities ( $N_{e\text{opt}} = 1.0E+21 \text{ cm}^{-3}$  for Ne-like ions) to exploit the collisional pumping scheme. Therefore, recombination pumping, where excited ions resulting from recombination processes populate the upper levels and resonant photopumping where photon absorption populates the upper levels show promise for H-like ions. The optimal electron densities for these processes ( $1.0E+18$  to  $1.0E+19 \text{ cm}^{-3}$ ) are more accessible to Z-pinch plasmas. Recombination pumping relies upon a super-cooled nonequilibrium plasma that stagnates when the current is reaches zero. This avoids heating the plasma at the time of maximum density. The scheme requires a recombination time that is longer than the cooling time. Even though it is easier to fulfill this condition in a laser produced plasma, there is a proposal to implement this scheme in a capillary discharge (see Optics Letters, Vol.13, [1988], 565.)

According to Chichkov, resonant photopumping appears more promising. He described a possible scheme

where an accelerated plasma shell stagnates on a core of active medium. The X-rays produced as the shell's kinetic energy turns into thermal energy pump the active medium. The Z-pinch geometry is ideal for this scheme because the pump source completely surrounds the lasing medium. The scheme, of course, requires that the pumping and pumped transitions overlap within the line width. Chichkov showed some possible combinations of active and pump media such as O VIII - V XIX, F IX - Mn XXII, or Ne X - Ga XXIII. These pairs have pumps in the 1- to 2-nm range and emission in the 6- to 10-nm range.

Chichkov then discussed a universal photopumping scheme in which the same material is used as the pump and as the lasing medium. This would require that the electron density and temperature in the source be higher than in the medium. This scheme requires a filter for the 2s-2p radiation to prevent population of the lower level (2p) of the lasing medium laser transition. With this arrangement, the upper level (3d) populates only through radiative decays from the 4-p and 4-f levels, creating the population inversion required for lasing.

## Lectures on Related Subjects

The workshop also included lectures by HIF community researchers that work on related subjects. These lectures displayed very exciting results and could be the subject of special topical reports. Examples were

- Cross-section measurements of ion-ion and electron-ion impacts for heavy ions, E. Salzborn, University of Giessen. (Muller, 1988, 1988a). These collisions determine the performance, through energy losses and particle losses, of heavy ion accelerators and storage rings. Moreover, electron-impact ionization of multiply-charged ions is a fundamental process in the physics of HIF
- Particle-in Cell calculations of Light Ion beam Diodes, T. Westermann, KfK (Westermann, 1988; Seldner 1988)
- A discussion of shock capturing schemes in the numerical solution of hyperbolic equations (Munz, 1988)
- Numerical simulation of vortex sheets (Munz, 1988a).

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# PSYCHOLOGY

## International Society of Political Psychology - Tel Aviv, Israel

by William D. Crano. Dr. Crano was the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research European Office from June 1986 through August 1988. He returned to Texas A&M University, where he is a Professor of Psychology. Currently on leave of absence, he is serving as the Director of the Program in Social Psychology at the National Science Foundation, Washington, D.C.

The 12th annual scientific meeting of the International Society of Political Psychology (Society) was held in Tel Aviv, Israel, June 18-22, 1989. The theme of the meeting was "Sources, Management, and Resolution of Protracted Conflict." As is characteristic of this annual event, the organizers took good advantage of the opportunities for information exchange afforded by this convention of some of the world's best political psychologists (see *ESN* 40:11-12:399). More than 300 papers, colloquia, workshops, roundtable discussions, and invited addresses were packed into the 5 days of the conference. Given the conference's multiple-sessions format, I can report on no more than a fraction of all that took place. Accordingly, only a small, and probably nonrepresentative, sample of the presentations will be discussed. The choice of these papers, however, was not random. They were chosen because they dealt with important issues of more than simple academic interest; the research on which they were based was done well; and, the topic was judged to be of interest to a large proportion of nonspecialist readers.

With these criteria in mind, let me set the political stage for the meeting.

### Real-World Politics

More than in almost any other scientific group, the Society is concerned with events in the real world of international diplomacy. The aim of the Society is to apply scientific principles of behavior to better understand the workings of national and international groups. The Society is very well connected politically, and typically features well-known politicians in its plenary addresses. For example, in this year's conference, the keynote address was to be delivered by the Honorable Abba Eban, former Israeli Ambassador to the U.N. and the U.S. Illness prevented Eban from attending the conference, so Honorable Moshe Shahal, a Labor Party member of the

Knesset and Israel's current Minister of Energy, took his place. Shahal started the conference off with a bang (and made the afternoon papers) when he declared that under appropriate conditions, he would be willing to negotiate with the PLO, words never before uttered by one so high in Israel's ruling hierarchy. (Of course, I don't understand why the Minister of Energy would be negotiating with the PLO).

Two days later, Egypt's Ambassador to Israel, the Honorable Muhammad Bassiouni, and his Israeli counterpart, the Honorable Shimon Shamir, met in a friendly discussion of their perceptions of each other's country. Being unacquainted with the subtleties of diplomatic English, I could not determine if anything of real importance was being exchanged.

### The Sons of Solidarity

At the Ambassador's tea, Dr. Janusz Reykowski, a member of Poland's Politboro, psychologist, and distinguished fellow of Poland's National Academy of Science, addressed the conference and discussed the revolutionary changes that have occurred in his country over the past 2 years, and the social and psychological processes that gave rise to them. Since Reykowski was the administration's principal negotiator with the Solidarity movement, this insider's view was fascinating and informative, if perhaps not completely acceptable at face value.

Reykowski's presentation, which he entitled "Experiences of a social psychologist who by historical accident found himself in the middle of a revolution," provided an interesting historical and psychological context for understanding the changes currently taking place in Poland. In his view, Poland, a country in transition, is attempting to replace a rigidly controlled political and economic system with one that is responsive to "market mechanisms" (his term), including more emphasis on the private sector. He would not predict the systemic outcome of the

revolution but, significantly, would not discount the possibility that a capitalistic economic system could emerge.

Reykowski traced the roots of the Solidarity movement to the end of World War II, when a new social order was brought in on the back of the Russian Army. The social, political, and economic infrastructure of the country was in chaos, and the Russians, although hated, offered the promise of social justice. Whether this promise was kept is open to interpretation, but there is no doubt that the society changed. For example, at the end of the war, there were only 80,000 people in the country with university degrees. Today in Poland, there are 1.5 million college graduates and a comparable increase has been seen in the proportion of skilled (high school- or technical school-educated) workers. Ten years ago, this new middle class (in the form of the Solidarity movement) put enormous pressure on the leadership of the country for greater political freedom and social justice, and in so doing, brought the country to a standstill. The government sought, but failed, to eradicate Solidarity. However, the Communist Party was able to deal the movement a very damaging blow. At the same time, it attempted to co-opt the movement by offering various economic reforms, but without the massive social changes necessitated by the magnitude of the problems that were faced, no real systemic changes occurred.

This failure to change anything but surface appearances led to the next phase of the movement, which we have been witnessing for the past 2 years. This movement is not led by the old guard Solidarity union, but by radicalized youth, the sons of Solidarity, as it were. It was the young radicals who organized the recent strikes, sometimes in opposition to Solidarity. The old union of workers and intelligentsia, of which Solidarity was constituted, played only a secondary role in the most recent Polish revolution. Rather, radicalized youth, highly organized, disillusioned with their prospects, and unwilling to take the counsel of their older peers, began the movement which has led to the reduction of the Communist majority in the Polish Parliament from 100 percent to 65 percent; this is all the more impressive when one realizes that a limit of 35 percent opposition was imposed by the Communist Party. Thus, the opposition was as successful as it could possibly have been.

Turning our attention to the conference, the final day included a tour of Jerusalem (with appropriate avoidance of unsafe areas of the city, given the ongoing uprising, or intifada), an afternoon address to the group by a Palestinian speaker, a debate on the subject of "Pathways to Peace," and a farewell dinner at the Israeli Knesset, hosted and addressed by the Honorable Moshe Arens, Foreign Minister of the State of Israel.

In terms of the geopolitics of this troubled area, this list of leaders strikes me as an all-star cast. The annual meeting was true to its purpose to bring social and beha-

vioral scientists face-to-face with policy makers whose decisions could have important and major effects on world events.

Now, what about the science? In the sections that follow, I will present a brief digest of some of the sessions. For reasons discussed earlier, these descriptions are meant only to provide a flavor of the talks, rather than a complete summary. However, a complete list of the program can be obtained from the conference organizer, Dr. Danny Bar-Tal, Department of Education, Tel Aviv University, Ramat Aviv, Israel, and written reports of all presentations can be obtained from the authors, whose affiliations are listed in the program.

### **Border Disputes: Theory and Research**

Chaired by Dr. Thomas Princen, Princeton University, Princeton, New Jersey, one of the most interesting sessions was about border disputes. We learned that border disputes are disagreements between two sovereign states, but they differ from more major confrontations along four critical dimensions:

1. The gravity of the dispute is perceived as important even by the protagonists, but not of earthshaking proportion.
2. Attention typically is focused directly on the issue in dispute. Given the relative importance of the dispute, proxy issues are not substituted, and proxy players are not made to stand in for the aggrieved parties.
3. Issues tend to be tangible rather than ideological.
4. Decision-making is localized--third parties are not widely used.

These features of border disputes provide social scientists with a real-world laboratory with some very interesting characteristics. First, border disputes can be studied--they are not so grand as to be intractable. Second, they are important because the decision processes and tactics of argumentation employed in them may be very similar to those used in more dangerous, intractable, global-power confrontations. As such, the border dispute provides a real-world analogue of a relatively controlled laboratory study, with all the attendant gains that such a controlled environment affords.

Dr. Jay Rothman, Tel Aviv University, Israel, provided one example of using a border dispute in his discussion of a recently settled border problem involving Egypt and Israel. At Taba, a garden spot, the Israelis had established a community. However, by a 1979 Egypt-Israel treaty, Taba was to be acknowledged as Egyptian land. The changeover agreed upon in the treaty was successfully realized; the Egyptians now own Taba. In return, the Israelis have constructed a luxury hotel there, and are encouraging Israeli tourism.

Rothman found in the Taba episode the seeds of some important understandings concerning resolving conflict.

To be sure, the dispute took much longer to solve than it should have; on the other hand, the exchange was made without bloodshed. In resolving this problem, three central stumbling blocks to successful conflict resolution were avoided. First, Rothman found that in many previously unsuccessful border conflicts, the negotiations were focused strictly on resources, and neglected important, if somewhat intangible, issues of national identity and national pride. In the Taba episode, care was taken to assuage the feelings of both powers, giving Egypt the land they desired, while giving Israel access to the land. Given the lack of strategic importance of this site, coercion was not a part of the negotiation. That is, neither Egypt nor Israel viewed Taba as sufficiently important even to resort to threat. (We have known since the early days of social research that having the power of threat or coercion adds appreciably to the time it takes to settle a dispute.) Though both sides had such power, neither used it. As such, this restraint facilitated the successful negotiations.

Princen noted another feature of the Taba dispute that might have some utility to students of conflict reduction. He found that in many border disputes, the problem to be decided is quite circumscribed. Sometimes, nations build in additional issues in their negotiations. Sometimes, these added features retard progress. However, in some circumstances, they can lead to a broader understanding between (former) protagonists. The test remains to be done, but it seems to me that previously successful examples of this "added issues" approach have kept to tangible, rather than ideological, issues. Adding issues that do not affect national pride would seem to offer greater opportunity to develop a more widespread agreement or consensus, thus fostering better relations between previously unfriendly states.

## Groupthink

Shortly after the Bay of Pigs invasion, President John F. Kennedy was said to have wondered how he could have been so wrong--how he could have been so misled by his advisors, so mistaken in his assessment of reality, so disastrously overly optimistic about the prospects of the success of a mission that, in retrospect, was doomed to fail from the start. In his work on groupthink, Irving Janis, noted Yale psychologist, studied this and other critically wrong decisions (see Janis, 1972). Originally, Janis defined groupthink as "A mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action." In other words, groupthink is a failure in a group context to exercise critical judgment. A premature consensus appears to form in the group, and all involved in the decision appear to line up behind it. Alternative positions sometimes are not even brought up,

much less defended; doubts are never aired, and a sense of wild overoptimism appears to prevail. In the Bay of Pigs case, some of Kennedy's counselors admitted later to having severe doubts about the wisdom of the venture; but none voiced these critical thoughts when they might have mattered. And so, the disaster occurred.

Obviously, groupthink can be devastating. The possibility that such faults in the decision-making process can occur is dangerous in any context, but especially dangerous when momentous issues of war and peace, of national security, of freedom versus slavery are at issue. As such, it is important to understand this phenomenon, if only to be able to ward off its dangerous influences.

There appear to be three antecedent conditions to groupthink:

1. The decision-making group must be stable and highly cohesive.
2. Certain structural features that tend to retard debate must be present.
3. The decision must be made in the midst of a provocative situation, which results in high stress and a threat to self-esteem or self-confidence.

Under these circumstances, groupthink becomes all too possible. In a discussion of their work on groupthink, Paul 't Hart, University of Leiden, the Netherlands; Marceline Kroon and Dik van Kreveld, University of Utrecht, the Netherlands, described their experimental work on groupthink. Their research was motivated by their perceptions of the shortcomings of Janis's work, and their results appear to have reinforced their attempt to overcome these shortcomings.

The most obvious problem with the construct of groupthink is the relative lack of controlled research devoted to its understanding. Obviously, given the antecedent conditions noted earlier, it is difficult to transport this phenomenon to the research laboratory. However, to understand groupthink, it must be studied under conditions in which the behavioral scientist can exert control over the factors that exist within the group under investigation. This suggests that the typical post hoc analysis of flawed political decisions be substituted by rigorous experimentation, and this is precisely what 't Hart and his colleagues attempted.

In their research, 't Hart and company took several pre-existing groups, and put them in an isolated experimental context in which they were expected to produce a decision. In the study, participant groups were given a case description of a prison, and asked to play the role of prison managers. The prison was in a terrible state, with rioting prisoners, disaffected guards, and a defective alarm system.

The "managers" were to decide upon a course of action. Two critical manipulations were undertaken: (1) the extent to which group, individual, or no accountability for the results of the decision was emphasized; and (2) the

perceived importance of the decision (money was offered to some subjects, contingent upon their developing the best solution). The central dependent measures were concerned with the quality of the plan, the time required to formulate it, and group members' attitudes toward one another.

Results suggested that the accountability manipulation was successful in differentiating groups in terms of decision quality. When subjects were held personally and individually accountable for their decisions, the decisions themselves were of a higher quality than when accountability was shared, or when accountability was not even mentioned. In addition, decisions were less risky in individual accountability groups, and they were made more efficiently.

This is an impressive initial effort to bring the study of this important phenomenon under the tight control of the experimental laboratory, while retaining some real-world features. The results point to a useful corrective in decision-making groups, namely the focus on individual accountability. Much remains to be done in this field, but the research by 't Hart and his colleagues has provided a good starting point.

## Authoritarianism

In 1950, Adorno et al. published *The Authoritarian Personality*, a book that had a massive influence on social and personality psychology for nearly a decade. The book described a syndrome of traits that presumably gave rise to the individual who would blindly follow the orders of an authority, no matter what the morality of those orders might be. This tendency was related to ethnocentrism, antisemitism, and political and economic conservatism. This syndrome (a medical term, which suggests a constellation of concurrent symptoms) was called the authoritarian personality. The authors of this text were refugees from Hitler's rabid philosophy, and as such, had both a personal and scientific interest in developing this work. Unfortunately, criticism of this work--primarily on methodological grounds--occurred almost concurrently with its publication. This did not stifle interest in authoritarianism; indeed, it has been cited in the scientific literature more than 1,800 times since 1960. However, current views on authoritarianism would not prove very positive; most consider study of this phenomenon dated, based upon instruments of suspect reliability and validity.

However, recent research in the Netherlands might call for a re-evaluation of this opinion. Dr. Jos Meloen, Center for the Study of Social Conflicts, University of Leiden, has argued that much of the methodological criticism of the authoritarian personality research group, while technically correct, would not result in any major changes in interpretation if undertaken. So, although it is true that the measurement scales suffer from various

technical shortcomings, correcting these shortcomings would not alter the standard results in any major way.

In his attempt to resuscitate the authoritarian personality, Meloen conducted a meta-analysis of work undertaken on this construct. Meta-analysis is a statistical tool by which the results of multiple studies on a given construct (in this case, authoritarianism) can be combined, and the strength of its effect on behavior assessed across the entire spectrum of published research. In all, Meloen sampled 125 publications containing 350 different respondent samples and more than 45,000 respondents.

Using this massive data base, Meloen attempted to determine if scores on measures of authoritarianism would predict

- Whether high authoritarians would be more likely to belong to, or sympathize with, proFascist or antidemocratic organizations
- Whether low authoritarians would be more likely to belong to, or sympathize with, antiFascist or prodemocratic organizations.

The results of Meloen's study support these expectations. First, groups showing some association with ultranationalism, Fascism and antisemitism, racism, Apartheid, and National Socialism all scored higher than other groups on measures of authoritarianism. Additionally, those active in such organizations typically scored higher than rank and file.

Low scoring groups gave the opposite picture. Groups identified as belonging to the *counterculture*, conscientious objectors, conscripts (versus Army volunteers), or members of liberal political groups all scored lower than average on authoritarianism measures. These results, based on many different modifications of the original authoritarianism measure, suggest that there is some consistent feature underlying authoritarianism, that measurement shortcomings did not compromise completely the validity of the ideas of the original work.

A similar conclusion might be drawn from the work of Dr. Cees Middendorp, Erasmus University, Rotterdam, Holland, who investigated the effect of authoritarianism on the Dutch vote from 1970-1985. In an impressive series of investigations, Middendorp sought to determine if a systematic relationship existed between personal authoritarianism and support of right-wing political parties. Although the results are qualified somewhat by age and social class, the answer to this implied question is affirmative. All other things equal, the more authoritarian the individual, the more likely he or she was to vote for right wing political parties. Middendorp's sophisticated statistical analysis (a structural equation approach, using LISREL) showed that this relationship was primarily a function of the overwhelming effect of religiosity on vote pattern. Put more simply, respondents who reported the greater religious involvement also showed the strongest

tendency to vote for right-wing parties. And, in a finding that replicates considerable U.S. research, such individuals also score high on authoritarianism. So it is not authoritarianism that appears to be the prime culprit in contemporary Dutch politics, but rather the combination of this tendency with conservative religious involvement.

Although nothing was said of the relationship between authoritarianism and the tendency to succumb to groupthink, I believe that such a combination might produce some fascinating ideas. 't Hart's work suggests that people contribute to groupthink by failing to voice their concerns about a plan around which consensus is forming. Clearly, if the authority (in the Bay of Pigs, JFK) appears to be on the verge of accepting a groupthink-inspired plan, then it is obvious that a person high in authoritarian leanings would be hardput to voice an objection to the plan. Such would cause a direct confrontation with the authority figure, and this is exactly what the authoritarian wishes most to avoid. Accordingly, there would appear to be a clear relationship between authoritarianism and groupthink, and I hope that this link will come under close scientific scrutiny in the near future.

### Psychoanalytic Theory and Political Psychology

A considerable portion of the conference sessions was devoted to an application of psychoanalytic theory to past and current political behaviors. Since this theoretical orientation is very distant from my own training, I will not attempt a thorough review of this section of the conference. However, there were some very interesting papers presented by psychoanalytically oriented speakers, and I will discuss one of them very briefly to provide a flavor of these works.

In an interesting discussion of Jewish responses to the holocaust, Dr. Frank Stern, Institute for German History, Tel Aviv University, Israel, began with a story of a middle-aged man being freed from Auschwitz by the Allies at the end of World War II. His comment upon leaving that terrible death camp was, "The Germans will never forgive us for this." In this simple sentence, Stern has clearly identified a very interesting psychological anomaly, namely that victims of persecution often assume the guilt of their tormentors. This strange phenomenon is seen in cases of

child and wife abuse and in situations involving the subjugation of entire classes of people, as in South Africa. And, the phenomenon seems to work the other way too: those who persecute and subjugate others come to feel (if they did not originally) that this behavior is deserved--that the victims deserve no better. Stern explained that the self-justification of the aggressor is perhaps understandable, since he or she otherwise would be unable to explain or rationalize their otherwise inexplicable actions. We must understand, too, that the victim must make sense of his or her world, and one way of doing this is to assume that the cruel treatment was deserved. This is an abnormal and unusual reaction, but it is not rare.

### Conclusion

The International Society of Political Psychology is a varied group composed of historians, philosophers, sociologists, political scientists, and psychologists. The features of the intellectual terrain that they find most interesting have to do with real-world problems of interpersonal and intergroup relations. They do not appear to shy away from tackling difficult problems; indeed, they seem to revel in them. This conference provided an excellent snapshot of the very diverse concerns of this group, their radically different research methodologies ranging from the psychoanalytic couch, to the antiseptic, and sometimes sterile, social laboratory, to today's media, to the written works of historians long dead. The breadth of interests and techniques is what is most appealing about this conference, because such diversity has the potential to demonstrate the extent to which we share common concerns, and to provide new insights into long-standing and vexing problems. I have tried to suggest some integrations of areas that do not naturally coalesce in the research literatures of social science. Along the way, I have tried to provide a flavor of an important meeting. If I have succeeded in either of these tasks, I will count this endeavor as a success.

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# TELECOMMUNICATIONS

## Plessey Research and Technology

by J.F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for industrial assessment in computer science and telecommunications.

### Introduction

Plessey, a company with sales of about 1.5 billion pounds/year, employs more than 5,000 scientists, engineers, and technologists. The company is well known in the U.K. as a developer and supplier of System X, the digital switching system used by British Telecom.

Plessey carries out extensive research and development in solid state physics, integrated circuits, sensors and communications, and telecommunications and software. The current activities in each of these divisions are briefly described herein.

### Solid State Research Division

The major activities of this division are the fabrication of electronic and optoelectronic devices in III-V compound semiconductors. Research is also continuing in optical materials, acoustics, infrared materials and devices, molecular materials, superconductors and biosensors. The chemical laboratory, analytical services, and theory groups also belong to this division.

Metal organic chemical vapor deposition (MOCVD) is used to produce complex structures in both the gallium arsenide and indium phosphide alloy systems, resulting in devices like high electron mobility transistors (HEMT), heterojunction bipolar transistors, quantum well devices, lasers, and photoreceivers. Also, the growth of III-V compounds on foreign substrates, such as gallium arsenide on silicon, has been carried out.

The gallium arsenide integrated circuit program has concentrated on microwave monolithic, integrated circuits (MMICs) for application in radar and communications systems. The technological programs have resulted in the transfer to production of a 22-GHz MMIC process. Work has started on processes with an improved power handling capability for phased array radars and an HEMT-based MMIC process for increased frequency of operation and improved noise performance. Design and computer-aided design (CAD) objectives have been directed toward the production of gallium arsenide circuits

for phased array modules. One result has been a single chip with all of the transmit/receive and phase shift functions in an area of less than 10 mm squared. High speed digital circuits have been based on both field effect transistor (FET) technology and on bipolar heterojunctions. Both programs are collaborative European Strategic Program for Research and Development in Information Technologies (ESPRIT) projects and the current achievements are a 4-Gbit FET multiplexer and a 10-GHz bipolar divider.

The optoelectronics department has grown significantly because of participation in the European Community's Research in Advanced Communications for Europe (RACE) program and the transfer of the sensor activities from Roke Manor in order to take greater advantage of in-house technology. The development of components and subsystems for telecommunications accounts for much of the activity; however, work on defense systems is still at a significant level. Research has been carried out on high speed lasers and receivers for long haul and local broadband transmission as well as narrow linewidth components for coherent system trials. Work is underway on optical switching based on semiconductor material in addition to more complex devices based on lithium niobate. An important ESPRIT contract on the optical interconnection of very low spacing integrated circuitry (VLSI) circuits began in 1989.

A third major activity in the division is the work carried out on sensors and nonsemiconductor electronic materials. This work has concentrated on the use of pyroelectric and ferroelectric ceramic materials for infrared (IR) detectors. The current state of the art is 100x100 arrays for thermal imaging applications. A camera based on this IR array was demonstrated at the Farnborough International Air Show. The division is also running programs on IR windows, radar absorbing material, acoustical materials and devices, biological sensors, and the development of high temperature superconducting ceramics.

The principal task of the theory group is the modeling of electronic and optoelectronic devices, circuits, and

processes. The chemistry laboratory and analytical service provide the full analytical capability required for the characterization of advanced microelectronics devices and materials at the submicron level. The range of techniques includes transmission and scanning electron microscopy, electron probe microanalyzer, Auger electron spectroscopy, IR, visible and U-V spectroscopy, liquid and gas chromatography, and nuclear magnetic resonance.

## The Integrated Circuits Division

This division deals with research and development in silicon integrated circuits. Activities include research into new process, device, circuit, and CAD techniques, through the development of whole processes, circuit products and CAD systems, and the supply of prototype circuits.

The one-micron programs supported by Alvey and ESPRIT are near completion. The Complementary (Symmetry) Metal Oxide Semiconductor (CMOS) team has developed a one-micron process featuring trench isolation, which is almost unique in the world, and is now building a telecommunications exchange on a chip circuit that will handle data at an overall rate in excess of 1Gbit/sec. The bipolar team has, with their double polysilicon, trench isolated one-micron process pushed the world record for dividers to 10.7 GHz on the Alvey project and have produced a Direct Frequency Synthesizer. This synthesizer, with a 2-GHz clock, will synthesize waveforms from DC to 500 MHz and will change frequency in 20 nanoseconds. The bipolar team also contributed to the ESPRIT I demonstrator, a quad 512-bit shift register operating at 2 GHz and they are responsible for the final demonstrator--an 80,000 transistor HDTV circuit.

New programs on submicron technology are beginning, supported mainly by ESPRIT II together with the Information Engineering Directorate. There are projects on submicron (CMOS), non-volatile memory, silicon on insulator, sub-micron bipolar, process modeling, metalization, and pattern transfer. Plessey is a partner in three of the major technology integration projects in ESPRIT and is managing one of them.

In CMOS, there is a half micron process with analogue components and nonvolatile memory, a compatible cell library, and high level CAD tools to enable circuits of several million transistors to be designed in a few weeks. In bipolar, there is a half micron process capable of delivering 100,000-gate circuits with a maximum toggle frequency of 20 GHz.

Work has continued on a number of complex CMOS circuits for a variety of applications. The Alvey program on array processors produced two interesting architectures. One of these is used in a Coordinate Rotation Digi-

tal Computer (CORDIC) device that will be supplied to Plessey Semiconductors as an early product. It gives flexible and efficient computation of DSP functions such as polar to cartesian coordinate conversion and digital frequency synthesis. The second, a motion estimator, will be a key component in codes for both video telephony and HDTV. In the other Alvey program on fault tolerant design, chip design has been completed on a 32-bit complex floating point signal processing system with a complexity of one million components.

Now being evaluated is an Asynchronous Time Division (ATD) switch, which is the one micron trench CMOS technology demonstrator that has a complexity of 400,000 components and is designed to operate at 160 Mbits/sec. Another is a 24-bit block floating processor developed on the VHPIC Application Demonstrator (VAD) program under contract to Plessey Marine.

The working of 100x100 readout arrays have resulted in the demonstration of completely assembled and working pyroelectric infrared imaging systems.

In the RACE program on broadband networks, there has been further research into high performance bipolar circuits required for low-cost customer access at 560 Mbit/sec and transmission at data rates up to 10 Gbit/s. Switching circuits are also required and the ATD switch is of much interest. In the RACE program on video codes, the motion estimator chip has been adopted as one of the critical components.

Circuit performance has continued to improve and a divider circuit has now operated at 10.7 GHz and basic ring oscillator delays of 37.5 ps have been achieved. At the end of 1988, the digital frequency synthesizer chip (the one micron bipolar technology demonstrator) was produced and provided both square wave and triangular wave outputs. The chip contains over 5,000 components and operates at a clock rate in excess of 2 Gbits/s.

Design was also completed on high performance data conversion and memory circuits operating at 1.3 GHz for applications in direct radio frequency memories in military systems.

The CAD group consists of joint activity covering two sites. Its work is primarily directed towards application specific integrated circuit (ASIC) chip development. Aspects of ASIC design are covered from high level behavior and logic synthesis, through new testability tools, to advanced layout capabilities for VLSI designs of 100-k gates and beyond. Part of the work is collaborative with participation in three Alvey projects in 1988 and two ESPRIT II projects that began in early 1989. The group is also a member of the Edinburgh Silicon Architecture Research Initiative, which is aimed at the development of tools for behavioral synthesis. Tools developed are used by Plessey Semiconductors as part of their ASIC design tool set, and as internal tools for the development of standard catalogue parts. A Logic Synthesis system,

which converts a behavioral description into a logic design was developed in 1988. Also, a floor planner was developed that provides automated layout of channel-less gate arrays with complexities of 100-k gates.

## Sensors and Communications Division

This division explores advances in radio, radar, and electro-optic technology and identifies areas where new business opportunities exist.

The Electronics Warfare and Avionics Department has strengths in adaptive processing, radars and target signatures, real-time hardware simulation, and electronic countermeasures. It has pioneered a number of new products and added unique features to many others currently being produced by Plessey businesses. Examples are the Missile Approach Warning Radar and the Weapon Proximity Sensor, which are now major products for Plessey Avionics.

Recent research in the Array Processing Group has explored new digital technology applied to super resolution for direction finding and phased array radar. In 1988, work has centered on such applications as the MESAR advanced active phased array radar, as part of a major critical experiment within the NATO Anti Air Weapons System program. This year, the Sonar Systems team was integrated into the Array Processing Group because of the similarity of their signal processing methods and techniques.

The Radar Applications Group is pursuing a wide range of new techniques and has considerable success in harnessing new device technology from Caswell to create products that are only achievable with high degrees of vertical integration. Their work centers on miniature solid state systems, seeking to develop sensor technology and to create new markets.

The Hardware Systems Group (Group) produces large systems which, although lying within the product range of other Plessey business, are of a sufficiently specialized nature to require development close to the technology base at Roke Manor. Currently, they are completing a major target measurement radar for an export customer.

The Microwave and Optics Department's activities cover a range of applications extending from static measurements of temperature, pressure, magnetism, and many other physical parameters through the electromagnetic spectrum from high frequency radio to ultraviolet light. The Group's work has effectively enabled the transfer of novel technologies and components from the Caswell Laboratories through system design and evaluation to demonstrations establishing new product areas for the Business Divisions. These include polymeric and ceramic acoustical detectors, novel lens materials, optical

and radiation detectors, pressure sensors, pyroelectric and bolometric elements for the IR, monolithic RF detector arrays, and optical detectors and sources.

Successful ventures include one- and two-dimensional uncooled IR imagers and broadband data and communications links at millimetric frequencies. In the latter area, a major contract to develop a portable millimeter wave landing system was received. This operates in the oxygen absorption band, forming a highly covert communication system. A strong mathematical physics base, which has contributed to sensor system evaluation, has been of particular benefit to Plessey's role in the NATO identification program and the Strategic Defense Initiative.

The Radio Communications Department (RCD) has provided research at the systems level in support of the introduction of fully automated radio systems, relying on the power of modern VLSI to avoid the need for a skilled radio operator. The RCD has also established advanced signal processing techniques that enhance the reliability, consistency, and security of those systems, even when the radio signal is suffering from noise, fading, and interference. The RCD has advanced equipment technology necessary to make radio equipment smaller, lighter, and easier to use, as well as simpler and less costly to produce.

The Radio Technology and the Radio Communications Departments have been combined to produce a single group with experience in all types of radio communications covering both civil and military applications. Their work includes Pan European Digital Cellular Radio, digital cordless telephones, and smaller projects for a wide range of customers including Plessey and its related businesses, GPT and Orbitel.

The work on Plessey Adaptive Compass Equipment (PACE) has progressed significantly through the past year and has provided a major input into the Autoguide project in which Plessey Controls is a partner.

## Telecommunications Systems And Software Division

Much of telecommunications systems research is now done through collaborative European Community programs, ESPRIT and RACE. In Plessey's Public System's group, the large project, Broadband Local Network Technology, involves the design and prototyping of local distribution and switching systems of the future. This RACE project supports the introduction of an Integrated Broadband Communications Network (IBCN) for Europe in the late 1990s. Within this project, an Asynchronous Transfer Mode (ATM) is being developed for multiservice traffic such as speech, video, and burst data by the use of time division multiplexing of packetized data at high speed. Other activities in the public systems area



include Network Management and Security Systems projects.

In the telecommunications Private Systems domain there has been further expansion of the object oriented approach to software production and distributed processing. The ESPRIT Communications Systems Architecture project in this area will continue for another year but will be complemented through a RACE project, RACE Open Service Architecture (ROSA), that will generate a European-wide standard for common service provision. Several Customer Premises Network (CPN) projects are proceeding through RACE and ESPRIT. The Dynamically Adaptable Multiservice System (DAMS) is likely to provide promising new business systems products that bridge the gap between today's narrowband Private Automatic Branch Exchange (PABX) market and tomorrow's IBCN. This possesses the special features of being able to adapt to users' bandwidth demands and providing modular expansion for purchasers. Future business and domestic CPN products are also the subject of studies within RACE projects.

Software Engineering activities within the division are aimed at improving the quality of Plessey software. Formal methods involve the application of mathematical techniques to enable the development of provably correct software. Integrated Project Support Environments (IPSEs) are sets of upgradable software development tools accessed through a common database and will enable large scale software projects to be undertaken in a controlled manner, even by widespread teams. The IPSE team is currently involved in projects to develop IPSE support for formal methods and advanced broadband telecommunications systems.

Within the cognitive Engineering Group, the Human Factors team is concerned with taking the abilities and limitations of the user into account in the design of advanced computer systems. The main challenge is now at the cognitive level rather than the physical level where ergonomics research has been successfully applied. The team carries out user interface design and techniques evaluation projects and provides training and consult-

ancy to Plessey businesses. The Intelligent Knowledge Based Systems (IKBS) is a team that is concerned with the practical application of Artificial Intelligence (AI) techniques. One example is the development of a second generation IKBS for fault diagnosis in System X EXCHANGES. Other recent IKBS projects have included an expert system building toolkit, a generic system configurator, and a communications network design aid.

The main activity of the Future Systems team is the Battlefield Sensor Simulator project. This simulator will model the future deployment of British Army Sensors in West Germany, in real time. This highly parallel system uses over 100 Transputers and embodies some of the most complex software of its type.

Research in Advanced Architectures is being carried out for applications including radar data processing, command and control systems, and fast packet switching in telecommunications. Transputer-based systems have been developed with up to 350 times the computing power of a VAX 11/780. Other work includes the development of fault tolerant computer systems, architecture studies to exploit advanced optoelectronic and semiconductor technologies, particularly in the area of neural networks.

Pattern Processing research in the division is being carried out in vision research and handwriting and sketch recognition. Building on earlier image processing activities in the areas of sonar and IR guidance systems, one area of recent work has been concentrated on the development of a 3-D vision system for robotics and autonomous vehicle guidance. As part of an ESPRIT project to demonstrate manuscript entry into computer terminals, an outstanding performance has been achieved in word recognition accuracies for connected script. Another significant activity is signal classification for communications applications.

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# SUPRENUM: The German Supercomputer, An Update

by J.F. Blackburn

## Introduction

A detailed report on Superrechner für numerische Anwendungen (SUPRENUM) was given in ESN 41-2:71-75 [1987]. Since that time, a complete SUPRENUM system has been developed and was demonstrated during the Hannover Fair in April 1989. Briefly the SUPRENUM consists of bus-connected independent clusters each of which contains 16 working nodes, each with its own local memory. Communication between nodes in a cluster and between clusters is by message passing. On each node, the process execution and communication environment (PEACE) operating system is in operation. The system will have a front end processor using the UNIX operating system, through which the user will access the system. A SUPRENUM system with 16 clusters is expected to have a maximum performance of 5 gigaflops/second.

This report will duplicate some of the material in ESN 41-2 but will be more complete in several respects. It is based on discussions with Professor Wolfgang Giloi, director of the GMD Research Center for Innovative Computer Systems and Technology, Berlin, where the SUPRENUM architecture was designed and Messers Karl Solchenbach and Clemens-August Thole of SUPRENUM GmbH in Bonn, and material supplied by them.

The fundamental research and design idea for SUPRENUM was to use the following ideas: the users of supercomputers who solve challenging problems; the computer architects who specialize in parallel architectures, parallel languages and tools for parallel computing; and the numerical analysts who understand the use of fast numerical algorithms.

About a third of the manpower in the SUPRENUM project is devoted to hardware; another third to system software, programming environment, and tools; and the last third is used in application software.

The 16-node, 256-processor system, which is expected to be operational by year-end 1989, will be characterized by

- Highly parallel multiple instruction multiple data stream (MIMD) architecture with a peak performance of 5Gflops/s
- 256 computing nodes aggregated into 16 clusters
- Each node with 8 Mbyte of private memory (giving an overall main memory of 2Gbytes)

- Each node with a vector floating point unit (Weitek chip set 2264/2265) with performance 20 Mflop/s, if chaining is used
- Flexible two-level (intra- and inter-cluster) interconnection network based on very fast buses.

A 32-node system (two complete clusters) was demonstrated at the Hannover Fair, and the final 256-node system (16 full clusters) will be in operation by the end of 1989. The development of system software, compilers, tools, and application software is carried out in parallel with the hardware development.

The SUPRENUM project was conceived by Gesellschaft für Mathematik und Datenverarbeitung (GMD) as a large national joint venture. Its development is funded by the German government and participating companies. Thirteen partner institutions were recruited from industry, national research laboratories, and universities (see Table 1).

**Table 1. SUPRENUM Partners**

Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt	Krupp Atlas Elektronik GmbH
Dornier GmbH	Stollmann GmbH
Gesellschaft für Mathematik und Datenverarbeitung GmbH	Technische Universität Braunschweig
Kernforschungsanlage Jülich	Universität Düsseldorf
Kernforschungszentrum Karlsruhe	Universität Erlangen-Nürnberg
Siemens AG (Kraftwerkunion)	SUPRENUM GmbH, formed as the 14th partner

SUPRENUM GmbH is responsible for coordination and management of the SUPRENUM project; integration of the hardware and software components that are developed in the project; fundamental research and development; marketing of individual results, particularly the SUPRENUM systems; and conceptual responsibility for the further SUPRENUM development.

## The SUPRENUM System

**The SUPRENUM Node Architecture.** Each processing node (PN) is a complete single board vector machine running its own operating system PEACE and communicating with other PNs. A PN consists of

- Node central processing unit (CPU) (Motorola MC 68020, 20 MHz) with paged memory management unit (PMMU) (Motorola MC 68851) and scalar arithmetic processor (MC 68882)

- 8 Mbyte of node memory dynamic random access memory ([DRAM] 35ns static column access time)
- Pipeline vector processor (Institute of Electrical and Electronics Engineers [IEEE] double precision) with 2x64 k bytes of vector memory (static random access memory [SRAM] 20ns access time)
- DMA/address generator (MAP) for block transfer of data structure objects
- Communication coprocessor for internode communication.

The node CPU performs the operating system tasks and interprets the instructions of a program. For operation security, access to the code and the data objects of the operating system and user tasks residing in the node memory is protected by the node PMMU. The node memory is paged but not in the sense of virtual memory. Paging is a means of protection and providing fast block transfer DMA to the data elements in a page in a static column mode of operation. As the PMMU adds 45ns to a memory access, it is employed only on the first entry into a new page in order to exercise access right control. It is bypassed for all further accesses to the same page. The pipeline vector processor (PVP) uses the Weitek WTL 2264/2265 chip set in connection with a microcoded controller accommodated in one of the applications-specific integrated circuits (ASICs). At 20 MHz clock frequency, the PVP has a peak performance of 10 Mflops/s for single operations (IEEE standard double precision) and 20 Mflops/s for the chained operations, such as vector dot product. The vector memory (VM) ensures a sustained performance close to the peak performance. The PVP also performs the scalar floating point arithmetic operations. The scalar arithmetic coprocessor (SAC) provides the additional floating point functions such as conversion, trigonometric, and transcendental. The MAP allows for a high-speed block transfer of data structure objects (DSO) between PVP and VM, vector cache and node memory, and node memories of different nodes. Its microcoded address generators support all required access functions for the data-structure types vector and matrix. The MAP functions are performed by an ASIC. The communication coprocessor (CC) performs formatting, sending, and receiving of messages by hardware in the microsecond range, realized by an ASIC. All four coprocessors use the same coprocessor interface of the MC 68020, whose functionality has been expanded by a special coprocessor interface ASIC. There are also ASICs for functions such as memory error detection and correction (EDC), address decoding, data path multiplexing, and bus protocol handling. All ASICs are realized using complementary symmetry metal oxide semiconductor (CMOS) gate arrays from LSI Logic, Inc.

The node memory uses DRAM silicon memory devices (SMDs) with 1 Mbit capacity each. The various

static memories and the CMOS bus drivers are packaged as hybrid modules.

**The SUPRENUM Cluster.** A SUPRENUM Cluster consists of 20 nodes accommodated in one 19-inch rack. Sixteen nodes are processing nodes and three nodes are the cluster disk controller node (DCN), the inter cluster communications node (CCN), and the cluster diagnosis node (CDN). The nodes of a cluster communicate through the cluster bus system, which consists of two message switching parallel buses with 64 data lines each. Doubling the cluster bus including its controller logic, renders the cluster bus system fault tolerant and doubles the interconnection bandwidth in the cluster to a total of 320 Mbytes/s. Several nodes can communicate simultaneously by the cluster bus system. The first stage of the two stage interconnection network consists of the intra-cluster interconnection structures, and the second stage is formed by the inter-cluster interconnection structure. As long as the cluster size is kept sufficiently small, there is a very fast and economical solution for the intra-cluster structure in the form of the common parallel bus. A parallel bus can be wide; e.g., 64 data bits, and if short, it can be very fast. A parallel bus can be node fault tolerant by adding redundant bus lines. However, for fault tolerance combined with the highest interconnection bandwidth, the better approach is to double the parallel bus and have a bus arbiter that allocates to a requesting node either one of the two buses, whichever is free. To keep the buses short SUPRENUM designers restricted the number of circuit boards to a maximum of 20, assuming 20-mm spacing.

The clusters in SUPRENUM are connected by a torus structure, formed by a matrix of bit-serial ring buses which transit data at a rate of 2 x 125 Mbits/s on the basis of the token ring protocol. The net data rate, which the clusters of a torus must share, is about 20 Mbyte/s. Not more than 4 clusters are inserted in each ring, so that there remains enough interconnection bandwidth per cluster. Doubling the torus structure by having row rings and column rings doubles the interconnection bandwidth and renders the structure fault tolerant. In case of a ring failure, alternative routing is provided by the CCN in each cluster.

**The Node Operating System, PEACE.** SUPRENUM has a local node operating system in each node, while a global operating system exists only virtually. Its functions are performed in reality by the collection of node operating systems. The main tasks of the node operating system are local resource management, including access right control to memory; local process management; and interprocess communications.

PEACE is the SUPRENUM node operating system that supports the following features:

- Remote access of resources in other nodes

- Remote monitoring of system components in other nodes
- Dynamic reconfigurability of the system after detection of faults and dynamic reconfiguration for load balancing and service migration in user programs.

The means of structuring in PEACE are through processes and teams. Processes represent system components that render service to other such components. They are subject and object of access rights, and they allow the construction of dynamically reconfigurable systems. A team is a group of processes that share common access domains to intrinsic system objects such as files, memory segments, and processes.

A process requests a service from a remote server process by issuing a remote procedure call (RPC) message. Message passing is based on a synchronous communication mechanism of maximum efficiency. The core of PEACE's hierarchical structure consists of PEACE kernel, process server, name server, memory server, and team server. The functions of the PEACE kernel are

- Interprocess communication (supported by a specific communication coprocessor)
- Process and address space switches
- Propagation of traps and intercepts as messages
- Message routing.

The name server issues and monitors name spaces and service access points. The process server issues unique process identifiers and handles the dynamic process administration. The memory server issues segment identifiers and does dynamic management of memory objects. The team server handles a variety of specialized teams that function as administrators. Each administrator team; e.g., file administrator, usually encompasses several server processes. PEACE was designed in MODULA-2 language and was rewritten in the language C for performance reasons. PEACE is believed to be the fastest passing message operating system in existence.

**The SUPRENUM User Interface.** Impacts on how to use a high performance numerical computing device like SUPRENUM come from the major use of the system as a numerical supercomputer, specific architecture of the system, properties of the two operating systems (UNIX on the host and PEACE on the SUPRENUM kernel) the abstract programming model, and the user expectations.

The programming model is based on independent tasks exchanging messages. There is always an initial task and a set of node tasks. Usually the node tasks use the same program with different data. The communication model is asynchronous; e.g., a send operation performs without explicit blocking and without an explicit acknowledgement.

The PEACE node operating system provides lightweight process, organized into teams, a variable number

of teams on a node, a rendezvous mechanism for inter-process communication, hardware supported high-volume data transfer, and a remote procedure call mechanism based on inter-process communication as basic primitives. Remote procedure call is embedded in a distributed name space concept. The various name spaces are connected to each other like directories in the file system. PEACE is optimized for fast process switches and fast network-wide communication.

A task from the programming model is mapped to a PEACE team consisting of the application process, a mailbox server, and other servers like a name server and signal server.

The basic design decision is that the combined system is represented as a homogeneous UNIX system to the user, with the SUPRENUM kernel as a specific high-performance computing device. On the question of single versus multitasking, the smallest unit available for a job can be a single computing node or a cluster. A single node allows more flexible handling of user requests but the management overhead increases. Currently, the smallest unit available for a user job is a cluster.

If a partition is assigned to a job A, then no other job is allowed to use the computing nodes of this partition during execution time of job A. However, a user working on the host system is allowed to move data in and out of the clusters that are assigned to job A. Also, all types of system processes may run in the partition assigned to user A. This decision increases overall throughput by a usually minor decrease of system performance for a single job.

User jobs on the SUPRENUM kernel are started on the host by the SkX command, which allows the user to request a certain number of clusters and other resources. The SkX part runs under UNIX, it interprets the command line, initializes data structures for the job spooler, reads the UNIX environment, and controls the use of files. Then the SkX command sends the job request to the job spooler.

The job spooler controls a file-queue of Sk requests. There is a server called Sk manager, which manages the SUPRENUM kernel in terms of actually available clusters, nodes, and communication paths. By requesting information from the Sk manager, the job spooler obtains information on which parts of the SUPRENUM kernel are available for job execution. If there is a job waiting and the resources are available, the spooler forks itself and starts job execution.

The usual identification and access mechanism are extended to the SUPRENUM kernel. Files on cluster disks are owned by specific users, which yields read, write, and execution rights for the owner, the group, and others. By starting a job, the job executor initializes the name space of the job. There is a security server for this job, which is connected to the job name space. A file server is included in the name space. The file server may issue a getuid

remote procedure call, to which the security server replies with the user identification.

The UNIX environment is read and Sk-specific data are added by the SkX command, for each task this environment is at hand. By routines like `getenv` and `putenv` the environment can be read into user programs, manipulated, and put back.

The question of finding files in the SUPRENUM kernel is solved by the fact that logically a user is always at the same place in the file system during task execution; i.e., the current user directory of the host. All files in the SUPRENUM kernel, newly created or modified during task execution, are mapped by symbolic links in the current user directory by the full path names. This is self-documenting and enables the file server system to find the files. By the environment mechanism, a user can enter a local flag, which makes the local file server responsible for moving remote data to the local disk.

For connecting the host and the SUPRENUM kernel, there are special VME-boards that fit into the host system. The system is called CAC and it consists of a CAC/processor board and a CAC/SUPRENUM bus board, which connects the different clusters with the host system via the SUPRENUM bus, a 125-Mbit/s serial link. On the CAC/processor, a special version of the PEACE operating system runs with special device drivers. Logically, parts of the PEACE environment are emulated in the UNIX environment, which allows the initial task to run on the host system. Also, the initial task can run in the SUPRENUM kernel. Then, only a few servers run in the UNIX environment providing for file access, graphics support, and other functions, while most of the servers run in the Syprenum kernel. This is faster, but there are limitations like a fixed amount of memory on a node in the SUPRENUM kernel.

As described above, a system of servers is used to realize the user interface. At the outer level, there are sk and job manager for execution of jobs, the file server system including the various disks servers, and tty servers for atomic input/output (I/O) operations on ttys. Included in the run time system, there is one security server per user job; an individual file server per job name space; a mailbox server for synchronous communication; a name and signal server and optional server for mapping, performance data delivery, accounting, and related tasks. A distributed debugging system is available, which can be initiated during job execution.

**SUPRENUM-Fortran.** With the advent of the new Fortran 8x standard, Fortran will be an up-to-date language. However, standard Fortran has to be extended by various features to support the SUPRENUM MIMD/SIMD architecture in an optimal fashion.

The SUPRENUM machine is characterized by MIMD parallel processing and SIMD vector processing within each process. A special SUPRENUM-Fortran

language has been defined and a new compiler has been developed. SUPRENUM-Fortran is based on Fortran 77 and extended by MIMD constructs, SIMD constructs, and miscellaneous extensions.

**Parallel Programming for SUPRENUM.** Application software development for SUPRENUM can be based on a very general programming model, the Abstract SUPRENUM Machine. The model allows program design in terms of concurrently executing, communicating processes and can be mapped to a wide range of MIMD-parallel, distributed memory systems. The Abstract SUPRENUM Machine consists of the following concepts:

- An application consists of a dynamical system of processes that are generated from independent program units
- There is an *initial process* that initiates the distributed application
- Each process can create other processes at any time, termination of a process is an internal event; e.g., by executing a STOP
- Termination of the initial process, however, will end the distributed application
- Processes have access to private data space only
- Interprocess data requests are handled strictly by message passing
- Process system can be of arbitrary structure
- Vector and array processing can be programmed for within processes.

Processes will usually be thought of as executing on individual processors (nodes), with the initial process being located on a front-end processor. Vectorized operations will be assigned to the vector floating point unit in a node. There is no need to be concerned about these aspects for program development. For example, an application designed to include a certain number of processes may actually run on a smaller number of processors, with lower performance, but without any implications for the development of the program.

The layout of a parallel application in terms of the Abstract Machine Concept proceeds as follows. The initial process is written as a single main program that will take care of creation and initialization of the process system and for general I/O. All other processes are executable copies of one or several task programs, which are written according to the chosen parallelization strategy. In grid based applications, the same task program usually codes for all necessary operations to be performed on a part of the grid. In other applications there might be independent algorithmic components that can be programmed for concurrent execution. Creation of new processes and message-based data exchange are programmed for whenever needed, wherever suitable in task programs or the initial program. When a portion of code

in a task program suits vector processing mode, the programmer may choose to use SIMD parallelism within the MIMD parallelism by writing vector instructions explicitly.

The Abstract SUPRENUM Machine can be used to map high level parallelism identified in an intended application onto an efficient process structure, before taking pains to code it in a particular programming language for a particular system.

To support the model, SUPRENUM provides two programming languages that directly provide language extensions--SUPRENUM Fortran and Concurrent Modula 2. Fortran is the most widely used language for scientific computing.

As an example, SUPRENUM-Fortran may be used effectively to realize an abstract model of a relaxation algorithm as it might be used in solving boundary value problems for elliptical partial differential equations:

#### Initial Process

- Get grid dimensions and problem parameters interactively
- Create a two-dimensional array of processes executing the relaxation program and send parameters of the application; e.g., identifications of neighboring processes, grid, subgrid; and process array extensions to either process as well as initial data on the corresponding subgrid
- Receive solution data from the processes and establish global results
- Stop.

#### Node Process

- Receive parameters and initial data for local subgrid
- Perform computations, essentially the conventional relaxation routine
- After each computational step, update values in points near inner boundaries by mutual exchange with neighbor process
- Retrieve and send out global results (residuals norms), preferably along a tree-like structure
- Send results to host.

The initial process is written as an initial task program, whereas the node processes can be generated from one task program. Tags can be used to make asynchronous user data exchange between processes logically safe, and to ensure that computational parts are written in common Fortran 77 throughout and kept distinct from communication parts. Thus, large parts of existing Fortran code, written as subroutines, can be reused unaffected by parallelization requirements.

**Application Software for SUPRENUM.** About a third of SUPRENUM development resources has been spent for application software development, which covers the implementation of new algorithms as well as the parallelization of existing codes.

The application software for SUPRENUM is based on the Abstract SUPRENUM Architecture; i.e., the parallel programs are formulated in terms of parallel processes. The number of processes and their topology (defined by the message passing communication) are primarily prescribed by the numerical problem and they are independent of the actual hardware configuration. The programming language for nearly all of the application packages is SUPRENUM-Fortran. Before the hardware was available, the application software development was done on the SUPRENUM simulator.

Application software packages:

#### (1) Linear Algebra

SUPRENUM provides parallel algorithms for linear algebra computation including: vector and matrix operations; elimination methods for linear systems with dense matrices (Gauss, Cholesky); elimination methods for systems with banded matrices (reduction methods); solution of eigenvalue problems; and iterative solvers for sparse systems (conjugate gradients, incomplete decompositions, block relaxation).

#### (2) Multigrid Software

A library of multigrid solvers for elliptic boundary value problems is available on SUPRENUM. The partial differential equations are of the type  $(Du) + cu = f$ . Different classes of coefficients and boundary conditions can be selected. The domain is two- or three-dimensional cube. The solvers are based on parallel multigrid algorithms. Because of their high degree of parallelism, they can be parallelized across the SUPRENUM nodes and can be vectorized within each node.

#### (3) Computational Fluid Dynamics

The routines in this category include potential solver, Euler solver, and Navier-Stokes solver.

#### (4) Other Applications

In addition to computational fluid dynamics, applications many different software packages have been adapted to SUPRENUM including structural analysis, quantum chromodynamics (QCD), and reactor safety.

The basic data structures for linear algebra calculations are matrices and vectors. Depending on the algorithm, matrices are distributed in rows, in columns, or in blocks (submatrices). The distribution is chosen according to these requirements: minimal number of communications steps, minimal length of communicated data, and maximal vector length in each process.

Vectors are distributed conforming to the matrix distribution. The linear algebra algorithms can be parallelized on block level, submatrices are treated independently and simultaneously.

For grid-based applications the SUPRENUM packages support two classes of grid structure: (1) Regular grids are characterized by direct addressing of the grid

points and a rectangular or cuboid address space. Geometrical neighbors are also logical neighbors. (2) Block structural grids are composed of several regular grids. Each single block shows internally a regular grid structure; however, the block structure itself is irregular.

A grid algorithm is a (usually iterative) method that calculates the value of a grid function at one point as a function of values defined at neighboring points. This is called relaxation. The iteration can be characterized as Jacobi-type in which a new iterate at a grid point is calculated using only old neighboring values or Gauss-Seidel type in which already calculated new neighboring values are used. The Jacobi-type methods are completely parallel since the calculation in each grid point can be performed independently.

The parallelism in the Gauss-Seidel methods depends on the order in which the grid points are processed. For Gauss-Seidel methods an  $N/2$  degree of parallelism (where  $N$  is the number of grid points) is obtained by "coloring" the grid points appropriately and processing all points of the same color simultaneously.

Standard iterative multigrid algorithms process a cycle from the fine to the coarse grids and back to the fine grids sequentially. Whereas, on each grid level, the actual problem is treated in parallel similarly to the parallel single grid algorithms.

**Communications.** In the SUPRENUM project, a library of communication routines has been developed which ensures clean and error-free programming, easy development of parallel codes, and portability within the class of distributed memory computers. Programs can be ported to any of these machines as soon as the communications library has been implemented.

The library supports regular and block-structured grids and is used by most of the SUPRENUM applications.

**Performance.** The quantities to be considered for performance of parallel algorithms are time  $T(N,P)$  - the time to solve a problem of size  $N$  on a multiprocessor system using  $P$  nodes; speed-up  $S(N,P) = T(N,1)/T(N,P)$ ; and efficiency  $E(N,P) = S(N,P)/P$ .

For Matrix and grid applications,  $(S(N,P))$  approaches  $P$ , and  $E(N,P)$  approaches 1 if  $P$  is fixed and  $N$  increases indefinitely. Estimated performance results for computational fluid dynamics applications are given in the following tables.

Three-dimensional potential solver with  $N$  approximately 200,000 grid points:

	$p = 16$	$p = 64$	$p = 256$
$E(200,000,P)$	0.98	0.97	0.85
Mflops/s	75	300	1040

Two dimensional incompressible Navier-Stokes solver:

$N =$	16,384	65,536	52,144
$E(N,256)$	0.62	0.85	0.95

The efficiency increases with growing problem sizes.

**SUPERB - The SUPRENUM Paralyzer.** Automatic vectorization of programs is a well-known technique and is used in practice. However, the automatic transformation of sequential programs for MIMD execution on distributed memory architectures, like SUPRENUM, is a research topic. The problem is the detection of locality in the memory references. The two basic kinds of locality for memory references are the matrix-type and the grid-type. The interactive system SUPERB is oriented to the parallelization of grid-type problems. It is designed for semi automatic transformation of Fortran 77 programs to parallel programs for the SUPRENUM Machine. The system is characterized by a powerful analysis component, a catalog of MIMD and SIMD transformations, and a flexible dialogue facility.

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# NEWS, NOTES, AND ABSTRACTS

## Fraunhofer Institut für Mikrostruktur Technik: Berlin, Federal Republic of Germany

Dr. Dean Mitchell

The Institut für Mikrostruktur Technik (IMT) of the Fraunhofer Gesellschaft was established in 1986 to provide a laboratory center specializing in research on X-ray lithographic and dry etch techniques for very large scale integration (VLSI) and submicron fabrication. The institute is located in the Dahlem district of West Berlin next to the Berliner Elektronenspeicherring für Synchrotronstrahlung (BESSY) which provides soft X-ray radiation for photolithography with 0.2 micrometer resolution.

The IMT is one of 35 applied research institutes in the Federal Republic of Germany sponsored by the Fraunhofer Gesellschaft (FhG). The FhG is the applied research analogue to the Max Planck Gesellschaft which supports basic research institutes. Both are legally independent nonprofit organizations that support research through contributions which come mainly from state and federal sources. The FhG also solicits funds from private industry for university-industry or institute-industry collaborative research projects. Industrial laboratories are generally quite reluctant to commit their own funds to such projects so that most of the research, including the industrial participation, is funded from governmental sources.

The goal of the research activities at IMT is the development of new technologies for VLSI on silicon with submicron dimensions for device features. The focus is on lithographic and dry etch techniques rather than on new devices as such. However, a significant effort is invested in developing techniques for fabricating submicron mechanical devices or hybrid mechanical/electronic devices. The hybrid devices have applications as sensors in microscale control circuits and in robotic machinery. Using single crystal silicon substrates and anisotropic etching methods, microstructural components have been "machined" in wafers which then could be incorporated with integrated electronic circuitry. One such application was the development of an accelerometer with 16 cantilever beams "machined" in the silicon substrate. The cantilevers had a seismic mass at the free end with detection by piezoelectric or capacitive coupling. Directional sensitivity and frequency selectivity could be incorporated in

a single device by appropriate placement and scaling of the cantilever beams. Other devices included thermally activated switches based on the bimetallic effect in cantilever beams as well as micromechanical switches and valves.

The IMT has a total of 40,000 sq. ft. of modern laboratory space which includes 10,000 sq. ft. of clean room facilities. There are 90 full-time staff members and 40 part-time workers, mostly students. In addition, about 20 scientists and engineers from affiliated semiconductor companies are working on projects at IMT at any given time. The affiliates include AEG/TEG, Eurosil, Siemens, and Philips/Volvo. The laboratory spaces are within a secure area so that proprietary research could be carried out, though I did not specifically enquire whether this is done.

Directed by Professor A. Heuberger, the IMT is organized in four technical sectors and a support sector. The technical sectors include technology base with groups for X-ray lithography, e-beam writing, ion-beam writing, mask repair, and etching; submicrometer process technology; computer-aided design (CAD) support technology; and, micromechanics with groups for silicon micromechanics, integrated microsystem technology, and ion projection.

The laboratory is well equipped and appeared to be operating efficiently. Adequate clean room spaces were available to carry out all stages of silicon processing from the bare wafers to the completed VLSI chip. The steps included all the normal growth, doping, annealing, and etching processes required for silicon planar technology. Specialized aspects of processing technology at the IMT include the provisions for submicron resolution in mask definition during exposure and the dry-etch procedures which maintain this resolution in processing. The specialized equipment includes a 50-K eV e-beam system with a minimum spot size of 25 nm that is used to generate master masks; a second-generation X-ray stepper from Karl Suss; and, a mask repair system for spots and pinholes larger than 80 nm. Exposure times of a few seconds are required for 2-inch wafers exposed on the BESSY beam lines.

In addition to the X-ray, Synchrotron Radiation (SR) source at BESSY, the IMT has a dedicated source called the Compact Storage Ring (COSY) which is being developed by the BESSY machine group in conjunction with



Siemens. The superconducting dipole magnets initially supplied by Siemens did not perform according to specifications and it was necessary to retrofit with resistive magnets until the problems with the superconductors could be resolved. This had not happened by the time of the visit. This delay may well have cost Siemens its lead as a potential supplier of commercial X-ray sources since Oxford Instruments has now entered the competition with a contract to build a compact SR source for IBM.

At the time of its inception in 1986, the IMT was the first fully-integrated silicon processing laboratory to have access to synchrotron radiation for onsite exposure of wafers. This is still the case although partial facilities for research and development on specific aspects of X-ray lithography have been developed at the SR sources at Brookhaven National Laboratory, Stanford University, and the University of Wisconsin in the U.S. The current status is evolving rapidly in the US with major new government investments in X-ray lithography centers at the major SR sources and with the construction of dedicated inhouse SR sources by AT&T Bell Laboratories and IBM.

## Synchrotron Radiation I: European Synchrotron Radiation Facility

Dr. Doan Mitchell

On 16 December 1989, the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, came a step nearer to reality with the signing of a convention and final act for its establishment by research ministers of eleven European countries. The signatories included: Belgium, Denmark, Finland, France, the Federal Republic of Germany, Italy, Norway, Spain, Sweden, Switzerland, and the U.K.

The conventions commit 2,600 million F (\$435 million) for construction of a 6-GeV synchrotron storage ring and 30 beam lines. The construction budget is in two phases: Phase I will construct the storage ring and seven beam lines by mid-1994 costing 2,200 million F (\$365 million); Phase II will cover installation of additional beam lines, (to 30 total) by 1998 costing 400 million F (\$70 million). France and Germany will provide the major share--58 percent--with Italy and the U.K. contributing 27 percent and the remaining partners about 4 percent each. The four Scandinavian countries are combined as a single entry for funding purposes. Annual costs for operating the ESRF are expected to run about 320 million F (\$63 million) when the laboratory reaches full scale operations in 1998. The cost of operations will be split among the participants roughly proportional to their commitments for construction.

The impetus to establish major new X-ray synchrotron sources in Europe and the U.S. came from the concerted

action by interested biologists, chemists, materials scientists, and physicists who developed the political support in their communities that was required for the commitment of funds on an unprecedented scale for the "small sciences." These moves culminated in 1984 with completion of the U.S. study and report on "Major Facilities for Materials Research and Related Disciplines," cochaired by Frederick Seitz and Dean Eastman, and the European report of the "European Synchrotron Radiation Project" (ESRP), cochaired by B. Buras and S. Tazzari. Both projects successfully obtained the necessary governmental approvals and funding authorities to proceed. The U.S. project--the 7 GeV Advanced Photon Source (APS) at Argonne National Laboratory (ANL)--is funded by the Department of Energy. The cost and time scales for the two projects are similar. Japan has an 8-GeV synchrotron radiation source planned for construction at Osaka with completion expected in 1994.

A visit to the ESRF in Grenoble reveals a large muddy field inside construction fences. The staff members are housed in prefabricated buildings or in temporary offices and laboratories provided by the Centre d'Études Nucleaires de Grenoble. The ESRF is located on the Rue des Martyrs convenient to the multinational Institut von Laue-Langevin (ILL) and the binational High Field Magnet Laboratory which is jointly supported by the Centre National de la Recherche Scientifique and the Max Planck Institute für Festkörperforschung in Stuttgart. Other national research institutes for low temperature research and solid-state electronics are located closeby. The location of the ESRF at Grenoble will give added impetus to its growing importance as a "science city" and center for emerging technologies.

While construction has not yet begun, a core staff including both accelerator specialists and synchrotron radiation scientists has been assembled. Ruprecht Haensel is the ESRF Director General and former ILL Director. J.L. Laclare heads the machine group, with G. Mulhaupt as deputy. On the scientific side, Massimo Altarelli and Andrew Miller codirect the scientific program which presently is staffed by 10-12 scientists and visitors. Altarelli and Miller, solid state theorist and experimental biologist, respectively, have (as major tasks) the development of scientific program as well as the hardware for X-ray beam lines with power densities on a scale not encountered previously.

A workshop on the use of X-ray synchrotron radiation for microscopy and microdiffraction was held on May 16-17, 1988. The workshop objective was to evaluate scientific opportunities and to provide recommendations on the instrumentation required when the source is operational.

High brightness X-ray sources can potentially provide "optical" microscopy on scales and with resolution limits comparable with high-resolution electron microscopy.

However, at present, electron microscopes operating in a transmission mode can focus to spot sizes as small as 0.3 nm for a beam divergence of 10 mrad. On the other hand, SR microscopes presently operate on a scale 2-3 orders of magnitude larger; i.e., spot sizes on the order of a fraction of a micron. The potential uses, however, are quite exciting, particularly in studies of "live" biological samples *in situ*.

The workshop reviewed designs for microscopes now being used or being installed. A photo-emission microscope is being installed at the W1 undulator at Haselab, Hamburg, FRG. The microscope will use mirror optics to obtain a spot size of 300 nm for wavelengths in the range 1-100 nm. A scanning transmission microscope is already in use at the SRS source in Daresbury, U.K., for studies of wet biological samples. The microscope can potentially achieve a 500-nm spot size for use in photo-electron microscopy.

Limits on microfocusing were discussed in context of beam stability and available focusing elements. Spot sizes of micron dimensions were considered to be at the edge of current feasibility. Strong recommendations were made for a program to develop micro-focus techniques at ESRF.

A workshop was held on March 20-22, 1989, to solicit user input on the types of beamlines to be installed initially at the ESRF. The experimental techniques and typical applications include

- Diffraction - PX, small molecules, and powders
- Elastic diffuse scattering - SAS, polymers, liquids and, amorphous solids
- Absorption spectroscopy
- High energy scattering - diffraction and Compton scattering
- Inelastic scattering - phonons and electronic excitations
- Magnetic scattering
- Topography
- X-ray microscopy - imaging, angiography, and micro-tomography
- Surface science - SEXAFS, surface diffraction, and standing waves.

The ESRF appears to be well on track. The national commitments for funding at adequate levels appear to be in place; the staff machine builders and research scientists are very capable with internationally recognized leaders. The Grenoble location may be fortuitous. The ILL was a European experiment in multinational cooperation that has been extremely successful. The selection of Haensel to lead the ESRF and the recruitment of other staff members with ILL experience will hopefully provide an infusion of the spirit of cooperation necessary for success.

## Steinbeis-Stiftung für Wirtschaftsförderung, Karlsruhe

Dr. Richard Franke

### Introduction.

Beginning in 1971, the Steinbeis-Stiftung established a series of technology transfer centers associated with the Fachhochschulen (Technical Universities) in Germany, to enhance the transfer of technical knowledge and expertise from these schools to industry, especially small companies who could not afford the necessary research and development personnel. Currently, there are more than 160 in Germany and some other countries. The centers are started with seed money from the government for necessary hardware and other expenses; however, after a certain period of time, the centers must become self-supporting or go out of business. The centers are associated with and under the direction of a professor at a Fachhochschule and concentrate on technology transfer in some particular area. Areas of interest range from biotechnology to robotics with special emphasis on computer-aided design/computer-aided manufacturing (CAD/CAM) technology.

The Technology Center for Computer Support in Mechanical Engineering (TZRM), Karlsruhe, was opened in 1985 and directed by Professor Dr. W. Hoheisel, the Fachhochschule Karlsruhe. My host was Mr. Paolo Saracelli. Activities are in CAD/CAM.

### Principal Activities.

- Training in using a CAD/CAM system, CATIA, and other smaller systems. CATIA is a product of Dassault, marketed and supported by IBM, and is widely used in the automobile and aircraft industry in Europe. The training facilities consist of an IBM 9377 computer, 9 graphics workstations, and 2 RT PC computers on which CATIA also runs. CATIA is a very large system and includes diverse capabilities in its many modules, including such things as NC models, 2- and 3-D design models, and wiring models.
- Consulting on CAD/CAM systems. To avoid conflicts of interest, it is usually determined beforehand that CATIA is not a suitable system for the client's application.
- Program development. These developments will in some cases enhance existing CAD/CAM systems, and in other cases may enable more efficient use of computational facilities, even though the calculations could be performed with a system such as CATIA. These projects may be carried out by a student at the Fachhochschule for part of the requirements of the Diplom degree (roughly equivalent to a Masters).

### Programming Support Areas.

- Developing programs for parts of a certain type, but which may depend on some parameters.
- Postprocessing for milling paths to enable the designed part to be milled. The center owns a small 3-axis milling machine so students can determine whether the proper part actually results from the calculations, or whether unforeseen problems with gouging occur.
- Transferring data between different CAD/CAM systems. This is generally done by going through a neutral (system independent) format such as IGES or VDA-FS.
- Linking programs to CATIA for new applications.
- Programming for applications that could be done in CATIA but are more efficiently done in a separate application program. (Two such examples will be discussed below.)

**Application Programs.** One current project in development of programs for CAD/CAM purposes to eventually be run on an independent system involves some interesting mathematical work. The problem concerns the design of hip joint replacements. In such cases, the original ball part of the joint is surgically removed from the thigh (to be replaced by an artificial one). The artificial joint is fitted inside the thigh bone and held in place only by the muscle and sinew of the leg. Using the current technology, the fit of the artificial joint into the thigh bone is not good enough to avoid eventual deterioration of the bone, so that typically after about 10 years the joint must be replaced. More than one subsequent replacement (without such severe deterioration of the thigh bone that no further replacement is possible) is unusual. The problem, then, is to design for the individual patient a replacement joint that results in much better match to the interior cavity of the thigh. Further, it is desired to be able to carry out the design and milling of the part automatically, from a series of digitized tomographic slices of the upper thigh in a short period of time; e.g., one hour. In addition, the kinematics of fitting the part into the thigh must be carried out in connection with the overall process of making the part fit the thigh bone of the patient. The mathematical aspects then are quite interesting. It is necessary to obtain a surface that is *cylindrical* shaped, as close a fit as possible to a series of essentially *circular* data sets, with the restriction that its *size* is monotone, so it can be inserted into the cavity. If the cavity is curved, additional restrictions may be necessary so the part can be inserted. Monotone approximation problems have received a lot of attention in the past few years, but this one has some interesting twists and I look forward to seeing the solution. The decreased length of hospital stays and increased longevity of hip joint replacement is

a clear-cut benefit to society (particularly the patient) a solution in which applied mathematicians can take pride.

Another project at the center involves approximation of gear teeth surfaces. The surface of the gear tooth is measured to high accuracy at a mesh (topologically rectangular) of points; and by comparison with the original shape at certain points, the amount of removed material (wear) is to be determined. Unfortunately, the measured data are probably not at the same locations as the points to be compared with the original gear. Thus, a high accuracy fitting scheme is necessary from which the (normal) distance from the original point to the worn surface can be computed. With the exception of the required accuracy, this problem seems relatively straightforward with a parametric spline surface being envisioned. The accuracy requirements will be helped in a practical sense by the fact that the locations of the measured data points are not very far from the points on the original surface, so only evaluation at points near the data will be required.

**Conclusion.** The Karlsruhe Technology Transfer Center occupies a necessary niche between the academic and the industrial setting, providing training and consulting in the use of CAD/CAM systems. Because of the nature of their charter, the projects are very applied, but sometimes involve challenging mathematical problems. Similar functions in the U.S. are more likely attempted by consulting firms with looser ties to academia.

### Geometric Modeling: Methods and Their Applications

Dr. Richard Franke

On April 24-26, 1989, I was one of the speakers at a small tutorial sponsored by the Spanish section of Eurographics, held at the Universitat Politècnica de Catalunya, Barcelona, Spain. The meeting was organized by Pere Brunet of the host institution and Hans Hagen of Kaiserslautern University, Kaiserslautern, the Federal Republic of Germany (FRG). The approximately 30 attendees were primarily from Spanish industry and universities, but the tutorial also attracted participants from the FRG, Belgium, the Netherlands, Norway, and Bulgaria.

There were six 2-hour tutorial presentations, as follows:

- Curve and Surface Design and Processing - Robert E. Barnhill and Gerald Farin, Arizona State University, Tempe, Arizona
- B-Spline Methods and Their Applications - Tom Lyche, University of Oslo
- Curve and Surface Interrogation and Spline Conversion - Hans Hagen, Kaiserslautern University and Josef Hoschek, Technical University Darmstadt, West Germany

- Scattered Data Interpolation - Gregory M. Nielson, Arizona State University, and Richard Franke, Naval Postgraduate School, Monterey, California (and ONREUR)
- Solid Modeling - Pere Brunet, Polytechnical University of Catalonia, Barcelona
- Solid Modeling and the Problems of Including Sculptured Surfaces - Ramon Sarraga, General Motors Research Laboratories, Warren, Michigan.

There were five demonstrations of CAD systems from industrial and educational organizations. Systems demonstrated were

- DMI System - Pau Planas, Polytechnical University of Catalonia, Barcelona
- EMS Intergraph - Francesc Casasayas, Intergraph, Spain
- Hewlett-Packard M-30 System - Dieter Roller, Hewlett-Packard, FRG
- APS-SS - Tor Dokken, Central Institute for Industrial Research, Oslo
- Sabrina - Peter de Mangelacre, Barco Industries, Spain.

The tutorials were mainly pitched at an intermediate level, with enough elementary material so that it was possible for novices to profit from the meeting, and enough pointers to more advanced material so that the more sophisticated likewise felt it had been worthwhile. A similar tutorial is planned for West Germany in spring 1990.

### Coherent Laser Radar Conference

Dr. Lothar H. Ruhnke, Atmospheric Physics Branch, Naval Research Laboratory, Washington, D.C.

The fifth in a series of specialized meetings on the subject of coherent lidar was held June 5-11, 1989, in Munich, Federal Republic of Germany (FRG). The meeting took place in parallel with the Laser 89 Optoelectronics and Microwave Exhibition and the 9th International Congress and International Trade Fair.

Most coherent lidar systems are used to remotely detect wind and turbulence. Whereas ground-based and airborne systems have been in use for some time, it was obvious from the discussions that space-based systems are now fast becoming the goal of most research. Within the European Space Agency, a satellite base system to measure wind on a global scale is under development. France, with strong participation from the U.K. and FRG, is developing the wind sensing system based on a CO<sub>2</sub> Doppler Lidar. So far, only ground tests and some air-plane experiments are visible, but an extensive study phase is underway to overcome the weight and power problems of a space-based system. In parallel, NASA

and the National Oceanic and Atmospheric Administration are developing a space-based wind sensing system, also using a CO<sub>2</sub> Doppler Lidar. The U.S. seems to be ahead of the European in this development.

Coherent systems in the near infrared (Nd:Yag) are becoming increasingly important. The lifetime of flashbulbs limits the application of Nd:Yag lasers in space systems. In the U.S., using diode pumping is being explored to increase lifetimes as well as to increase conversion efficiency and with it decrease power and weight. A European approach stresses using spare flashbulbs for space applications. Before a space-based wind sensing system becomes reality, information also must be gathered about the aerosol condition over remote marine areas.

### International Congress on Optical Science and Engineering

G. Charmaine Gilbreath, Optical Systems Section, Naval Center for Space Technology, Naval Research Laboratory, Washington, D.C.

**Introduction.** The International Congress on Optical Science and Engineering (ECO2) was held in Paris, France, April 24-28, 1989.

The European Physical Society, the European Federation for Applied Optics, and the International Society for Optical Engineering cosponsored the conference. The congress sponsored topical conferences, a technical exhibition, and an educational short course program. The 5th European Conference on Integrated Optics and a special session held in French on Fiber Optics and Applications were held in conjunction with the conference.

The ECO2 consisted of 19 topical conferences including sessions on materials and their applications, optical instrumentation for space-based applications, high power lasers and applications, optical pattern recognition, holographic optics, optical microlithography, and X-ray instrumentation. Six plenary sessions were held which included papers on superconducting light interactions, optical storage and scanning technologies, the objectives of the European Space Agency (ESA) earth observing program, and X-ray techniques for the physical sciences.

**Satellite Optical Communications.** The ESA has assessed the international optical communications arena and has selected as its area of emphasis technology relating to pointing, acquisition, and tracking (PAT). The objective of PAT in a free-space optical communications system is to couple the optical power from a laser source into a detector that is remotely located with maximum efficiency, where both the transmitter and receiver are typically in motion. Emphasis on developing technology in this area is a strategic move as there is a great need for compact, robust, facile, and lightweight systems to collect

and direct the light from the laser transmitter. The semiconductor laser intersatellite equipment (SILEX) program is tasked to develop an optical link between a geosynchronous and lower orbiting vehicle. The SILEX has defined its system to be a direct-detection link, based on 800-nm AlGaAs laser diodes, for a maximum range of 45,000 km with a data rate switchable from 15-120 Mbits/s. Under QPPM pumping, 30 mW of average output power are required. Stable operation under pulsed conditions up to 120 mW is specified and the spectral bandwidth under pulsed conditions must not exceed 4 nm.

Single-mode diodes from a variety of commercial sources are being considered for transmitters as well as multi-stripe phase-locked arrays. Avalanche photodiodes are anticipated to be the detectors. Papers were presented exploring alternatives such as using a diode-pumped Neodymium host laser as the transmitter in a direct detection system (A. Popescu and U. Johann). Although there were some papers presented that discussed heterodyning over direct detection, the ESA has decided to implement a direct-detection approach.

The U.S. was represented by several papers. Invited American papers included those by L. Caudill, NASA Headquarters, who presented an overview of NASA's optical communications efforts. Caudill's presentation included a review of the relatively short links designed to preserve the RF spectrum. NASA is funding efforts in direct-detection technology, coherent detection and an optical upgrade of the deep space probes. Vincent Chan, Massachusetts Institute of Technology, presented an invited paper on intersatellite optical heterodyne communications. James Lesh, the Jet Propulsion Laboratory, made an invited presentation summarizing the effort to upgrade the deep space probes to an optical link.

**Photorefractive Materials and Holographic Optics.** A special session on photorefractive materials was held and papers reporting results on these interesting materials were scattered throughout the conference. The photorefractive (PR) effect refers to the change in index of refraction induced by light incident on certain types of materials. The PR effect was observed in the piezoelectric family of  $\text{La}_3\text{Ga}_5\text{SiO}_{14}$  (S.B. Astafiev, et al.). The effects of proton concentration on iron-doped  $\text{LiNbO}_3$  were studied by R. Sommerfeldt and E. Kratzig. Increased proton concentration does not seem to have an effect on the PR effect but does increase dark conductivity. This latter effect can be ameliorated with annealing. Several papers in this area presented results using GaAs or InP. These materials are exhibiting PR effects at infrared wavelengths and are therefore useful with laser diodes and laser diode arrays. These papers represent a change in the trend in PR research toward materials which may be used with these devices.

Applications for photorefractive devices were presented in the context of real-time holography. Ex-

perimental results for nonplane wave two-wave mixing in these couplers were presented and discussed by the author and coauthor (G.C. Gilbreath and F. Davidson) and a paper by L. Pugliese and G.M. Morris presented experimental results whereby the PR device is used as a holographic imager. In the latter approach, a hologram is formed elsewhere and imaged into the PR material. The imaged hologram is then illuminated at the wavelength of interest to reconstruct the object beam.

**Plastic Fiber Optics.** Sessions were held in French on fiber optics and applications. In this topical conference, a series of papers was presented on plastic optical fibers. These fibers are made of a type of polymer with a flourinated cladding. In general, these fibers are quite lossy (100-160 dB/km). However, they are robust and easy to implement. These types of fibers typically are utilized to transmit at 560 nm and 650 nm, and are useful in short-path, industrial applications. An increasing paper was presented by Lecoy and Gauthier addressing the issue of insertion loss. Insertion loss, or the loss from coupling light from the optical source into the fiber, is a major problem in fiber optics. Lecoy and Gauthier reported efficient coupling with fibers that terminate in cones, where the cones are manufactured pursuant to a specific application. The fibers with cone terminations are monolithic and those that are antireflection coated yielded reflectances at .5 percent and transmittances of 85 percent.

### International Conference on Acoustics, Speech, and Signal Processing Society of the Institute of Electrical and Electronics Engineers

Drs. Clifford Carter and Roger F. Dwyer, Naval Underwater Systems Center, New London, Connecticut.

From May 23-26, 1989, the international conference on Acoustics, Speech, and Signal Processing (ASSP) Society of the Institute of Electrical and Electronics Engineers (IEEE) was held in Glasgow, Scotland, U.K. The ASSP is the fourth largest society of IEEE and with about 15,000 members, claims one-third of its membership from non-U.S. countries, reflecting the international diversity, interest, and contributions in this enabling technology field.

Seven parallel sessions were held in the Scottish Exhibition and Conference Centre (SECC), Glasgow, an ideal venue for this group of approximately 1,400 technical experts. During the 4 days, there were approximately eight half-day sessions. However, two sessions each day were reserved for poster presentations. Most sessions had about 10 papers--about 560 presented technical contributions--in the following topics:

- Speech: Discrete utterance recognition, speech coding, speech synthesis, speech enhancement and noise reduction; recent advances in speech

recognition systems, speech analysis and recognition, speaker and language recognition; speech analysis: pitch and format estimation, connected speech recognition, language processing for speech, hardware for speech processing

- **Digital Signal Processing (DSP):** Digital filter theory and design; quantization effects; adaptive filtering; discrete transforms; least mean square (LMS) and recursive least square (RLS) adaptive filtering; hardware and software for fast algorithms; new directions in adaptive filtering; DSP applications, filtering, and signal reconstruction; DSP in communications
- **Spectral Estimation:** System identification and signal estimation, spectral estimation, autoregressive-autoregressive moving average (AR-ARMA) estimation, time varying spectral analysis, eigen structure analysis, higher order spectra, deconvolution and radar
- **Multidimensional Signal Processing (MDSP):** Image restoration and modeling, computer imaging, MDSP theory and parallel implementations, MDSP algorithms, image restoration and analysis, image segmentation, measurement and recognition, vector quantization of images, knowledge-based systems and neural nets, image coding, motion and image sequence coding
- **Audio and electroacoustics:** Room/auditorium acoustics, recording and reproduction, aids to the hearing impaired and music analysis
- **Very Large Scale Integrated (VLSI):** VLSI numeric processing, VLSI architectures for two-dimensional processing, high performance VLSI processors, neural net architectures, VLSI methodology and implementation
- **Underwater Signal Processing:** Array processing, time delay estimation and source localization, sonar/radar detection and estimation, underwater acoustic signal processing.

Meeting size makes it impossible for one individual to attend all of the relevant presentations. A strength of the ASSP series has been the synergistic effect of several strong intertwined topic areas and exhibition of off-the-shelf electronic hardware for signal processing. From the opening session through to the end, it was clear that Glasgow was making a strong push to turn its economy from heavy manufacturing-based to high technology-based that could contribute to an economically unified Europe in 1992. One example of this was a tour of Motorola's semiconductor manufacturing plant, touted as being Europe's largest 6-inch facility and having produced 8 million wafers since opening in 1974, setting new standards in terms of product quality, equipment, and working conditions.

The strong technical program is attributable to the hard work of many individuals under the leadership of Professors Tariq Durrani, Peter Grant, and Roy Chapman. A published conference proceedings is available from the IEEE; but as with most conferences, more recent advances are discussed over meals, at the poster and meeting places, and during question-and-answer periods. Often times, two or three important new ideas will be sparked by work done by someone working on a closely related field and much time and effort can be saved by seeing the advances and hearing of the false starts and wrong paths taken by colleagues. Keeping abreast in the ASSP is partially accomplished through participation in the IEEE ASSP through individual membership and participation in the annual conference, which will be in Albuquerque, New Mexico, on April 3-6, 1990, and in Toronto, Canada, on May 14-17, 1991.

### 1989 Hewlett-Packard Europhysics Prize Awarded for Heavy-Fermion Superconductors

Dr. Alan F. Clark, National Institute of Standards and Technology, Washington, D.C.

The Hewlett-Packard Europhysics Prize for 1989 for outstanding achievements in solid state physics has been awarded jointly to Professor F. Steglich, Institut Festkörperphysik, Technische Hochschule, Darmstadt, Dr. H.-R. Ott, Laboratorium für Festkörperphysik, ETH, Zurich, and Dr. G.G. Lonzarich, Cavendish Laboratory, Cambridge, in recognition of their pioneering investigation of heavy-fermion metals. In 1975 the first indications of a new category of metallic compounds was given by the discovery that at low temperatures (.3 K) the specific heat of  $\text{CeAl}_3$  was proportional to the temperature, with a coefficient of proportionality about a thousand times that of Na, for example. It was as if the electrons were more massive than normal by about that factor. It was the discovery in 1979 of superconductivity in  $\text{CeCu}_2\text{Si}_2$ --a discovery treated initially with great skepticism--that really broke open the new field of physics. Since then it has expanded rapidly and heavy fermions have become a major area of research.

The Hewlett-Packard Europhysics Prize is awarded annually by the European Physical Society for recent work in condensed matter physics particularly where there could be important applications in electronic, electrical, or materials engineering. The award which includes a cash prize of SwFr 20,000. - (in total) was presented during the 9th General Conference of the EPS Condensed Matter Division, in Nice, 6-9 March 1989.

## Instabilities and Wave Phenomena in the Ionosphere-Thermosphere System, Kaluga, U.S.S.R.

Dr. Joseph D. Huba, Supervisory Research Physicist, Naval Research Laboratory, Washington, D.C.

On February 6-10, 1989, I attended an international symposium entitled "Instabilities and Wave Phenomena in the Ionosphere-Thermosphere System" in Kaluga, U.S.S.R. The symposium was hosted jointly by the Institute of Terrestrial Magnetism, Ionosphere, and Radio-wave Propagation (IZMIRAN), the Institute of Applied Physics, and the Radiophysical Research Institute under the auspices of the U.S.S.R. Academy of Sciences. The symposium was organized as a part of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) sponsored Worldwide Ionosphere-Thermosphere Study (WITS) project Instabilities and Nonlinear Effects in the Ionosphere/Thermosphere System (INEITS) proposed by the Soviet Union.

The symposium was divided into five sessions: wave phenomena in the upper atmosphere and related ionospheric effects, ionospheric irregularities, dynamics of the auroral ionosphere, Alfvén structures in the ionosphere, and ionospheric effects of electron precipitation. The nature of the research reported was on the 6.1 level.

Unfortunately, I did not attend the entire symposium because of a delay in receiving approval for the travel from the Office of the Secretary of Defense. Instead of arriving in Moscow on February 5, 1989, I arrived on February 8, and only attended the sessions held on February 9 and 10. I attended one session that had Soviet speakers; the topic was Alfvén structures in the ionosphere. The talks were highly theoretical; i.e., visuals were filled with equations and on a subject that we are not actively pursuing. Thus, I was not in a position to accurately assess the quality of the work.

I had lengthy discussions; i.e., 1 hour, with two Soviet scientists. The first was with Dr. Natan Blaunstein from Moldavia, U.S.S.R. He showed me results from a three-dimensional (3-D) electrostatic code he developed which describes the evolution of density enhancements in the ionosphere; e.g., barium cloud evolution. I was aware of this work and was favorably impressed with the quality of his results. Only within the last year have we developed this capability and I thought that we were the first to do so in the world. Although I did not have time to examine Blaunstein's results in detail, I noted that his results were qualitatively consistent with those obtained at Naval Research Laboratory (NRL), Washington, D.C. In particular, we both have found that the length of a barium cloud along the direction of the magnetic field can have a profound effect on the stability of the cloud--short clouds are much more stable than long clouds. Ironically, Blaunstein

seemed to be completely unaware of our recent work although it has been published in the open literature.

The second discussion was with Dr. L.M. Ezukhimov of IZMIRAN. This discussion was hampered because Dr. Ezukhimov's English was very poor; Dr. Ya. Feldshstein interpreted. In short, Dr. Ezukhimov was also interested in the 3-D dynamics of natural ionospheric irregularities. He showed me experimental results of power spectra of density irregularities which indicated that 3-D effects were important in the natural high latitude ionosphere. However, it is very difficult to explain these results with conventional linear theory. Dr. Ezukhimov asked if I was aware of these results, and if so, could I explain them; the answer was no in both cases. I had not seen these experimental results before and am somewhat skeptical that they are correct, or at least being interpreted correctly.

Overall, the trip was informative and interesting, albeit a short one. The Soviet scientists were very friendly and open with their research and seemed to be very motivated to establish collaborative efforts with foreign scientists. Moreover, I was impressed with the similarity of their research efforts on 3-D ionospheric dynamics with that are being carried out at NRL.

## The Gibraltar Experiment--Study of Linking Spain and Morocco Via Bridge or Tunnel

Dr. Thomas Kinder, Meso/Large Scale Physical Oceanography Program, Office of Naval Research and Alan Brandt, Coastal Sciences Program, Office of Naval Research.

The Sociedad Española de Estudios para la Comunicación Fija a Través del Estrecho de Gibraltar (SECEG) is the Spanish part of a joint Spanish-Moroccan institution to study the possibility of building a fixed link (bridge or tunnel) between Spain and Morocco. The Moroccan side is named Société Nationale d'Etudes du Détroit (SNED), and a senior SNED representative (Ahmed Khribèche) also attended the meeting. The SNED sponsored a Gibraltar workshop in Tangier during April 1986. The SECEG/SNED have high visibility within their governments. The charter for them was signed by the two kings in Fez in 1979. Although economic considerations are not presently favorable for either a bridge or a tunnel, joint environmental studies are being done and the two governments appear to view SECEG/SNED as a mechanism for mutual cooperation (Spain and Morocco have serious issues to resolve elsewhere, such as Ceuta and the Polisario/Sahara). There is also the possibility for a less ambitious fixed link, such as an electrical power cable.

The Instituto Español de Oceanografía (IEO), established in 1914, has its main office in Madrid, but several satellite laboratories: Fuengirola (Malaga), Vigo, Coruna, Santander, Palma de Mallorca, Santa Cruz de Ten-



erife (Canary Islands), and San Pedro de Pintar (Cartagena). It is somewhat analogous to the National Oceanic and Atmospheric Administration, with a strong emphasis on practical problems such as fisheries and pollution. The Madrid and Malaga laboratories have a long history of physical investigation in the Strait of Gibraltar and Alboran Sea, and both participated in the Gibraltar Experiment (see *ESNIB* 89-04:34-35). The most active Spanish physical oceanographer, Gregorio Parrilla, was a key player in the ONR-sponsored Donde Va experiment that was carried out by the Naval Ocean Research and Development Activity in the Alboran Sea during 1982. He was the key Spanish scientist in the Gibraltar Experiment.

A second Spanish agency, the Instituto Hidrográfico de la Marina (IHM), also played an important role in the Gibraltar Experiment. This institution, located in Cádiz, is analogous to the Defense Mapping Agency and Naval

Oceanographic Office. An arm of the Spanish Navy, the IHM's primary mission is cartography. The IHM does have a small subsection of oceanography, however, presently led by Antonio Ruiz. They have the capability for independent conductivity, temperature, and depth surveys, and also a modest mooring capability using Aanderaa current meters. Tidal prediction is one of the IHM tasks, and they routinely deploy and analyze sea level gauges (interestingly, IEO also maintains a tide gauge network). At present, Ruiz, who received his oceanographic education at the Naval Postgraduate School, Monterey, California, maintains a good working relationship with the U.S. Navy Oceanography Command Center in Rota.

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### Reports

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### Computer Science

**BRITE-EURAM 1989**, by J.F. Blackburn. (9-9-C) The second Basic Research in Industrial Technologies for Europe-Europe/America (BRITE-EURAM) conference was held in Brussels, Belgium, in winter 1989. The primary objective of the program is to make European manufacturing industries more competitive in world markets.

BRITE-EURAM builds on earlier work of the BRITE and EURAM programs that already support 300 projects. For 1985-88, BRITE had European Community (EC) funds of 185 million ECUs and supported 215 projects. For 1986-89, EURAM has 30 million ECUs and supports 84 projects. The four major technical areas are (1) advanced materials technologies, (2) design methodology and assurance for products and processes, (3) applications of manufacturing technology, and (4) technologies for manufacturing processes, each with several subareas.

In the opening address, Mr. Pandolfi, Vice President, The European Commission (Commission), stated that many BRITE participants have recently reported that they expect to realize commercial benefits from their projects within 5 years. Pandolfi urged that a strong set of links be created between different frameworks for Euro-

pean cooperation so ensure that EC R&D resources are used effectively.

In this report, Dr. Blackburn briefly reviews the following topics:

- The relevance of European community R&D program for industrial development
- Setting R&D priorities for an industrial company
- Customers, suppliers, and researchers: The opportunities and pitfalls in Europe for R&D collaboration
- Introduction of stability and plasticity phenomena into a computer-aided design project for metallic structures
- Predictive techniques for the analysis and design of fiber reinforced composite materials and structures capable of withstanding impulsive loading
- Development of standardized material transport devices for the sequential automation of the processing of flexible materials
- Two- and three-dimensional garment modeling
- Sensor technologies for machine control and condition monitoring
- Optical sensors and fiber optic wavelength division multiplexing for process control
- Adaptive control of laser processing
- Links between R&D and standardization
- Brief review of materials development and application
- Brief review of product assurance technologies



- Brief review of applications of manufacturing systems.

*The Commercial Opportunities for New Advanced Electronic Materials*, by J.F. Blackburn. (9-10-C) The British government is committed to collaboration in R&D, both at the national and European levels. Most research is now directed toward materials to be used in VLSI, and toward techniques for producing these chips and packaging methods.

Most of the papers dealt with materials at the chip level which is dominated by large-scale integration. Papers were presented on the following subjects:

- Advanced electronic material
- Government policy and support for advanced electronic materials Silicon VLSI technology
- Status of gallium arsenide technology
- Specialty chemicals and materials for electronics
- Optical recording technology and materials requirements
- Commercial exploitation of advanced electronic materials
- Commercial opportunities for optoelectronics based materials
- Infrared and optoelectronic materials and their applications: a MOD perspective
- Advanced materials for electronic displays
- Likely impact of the high temperature superconductors
- Amorphous semiconductor electronics into the 21st century

*International Open Systems Conference*, by J.F. Blackburn. (9-11-C) On March 21 and 22, 1989, at the International Open Systems Conference, London, U.K., papers were given on Open Systems Interconnection (OSI) Perspectives, International Aspects of OSI, Conformance Testing and Certification, Standard Issues, and Migration Strategies.

**OSI Perspectives.** Despite its original direction, the system view has been obscured. The following areas are important to establish the system context: (1) lower layers of the OSI Reference Model-Provision of the transport service, (2) application layer standard, (3) system building, and (4) major issues for a system approach.

**International Aspects of OSI.** Merging of telecommunications and computers leads to need for common standards in architecture and protocols in communication, and in operating systems and computer languages in computing.

**Conformance Testing and Certifications.** The conformance testing goal is to provide a base of discipline to the

implementors and confidence to customers investing in OSI. The basic goal of the Conformance Testing Service (begun by the European Commission in 1985 to promote information technology and telecommunications standards) is to enable conformance of information technology products to standards based on the principles of independence, mutual recognition, and standardization.

**Standard Issues.** Identified systems management functions are for object management, state management, relationship management, error reporting and information retrieval, management service control, confidence and agnostic testing, log control, software management, and security management. NATO has selected a subset of ISO security architecture options.

**Migration Strategies.** According to Mr. Paul Frost, OSI Manager, Employment Department, Training Agency, tactics are to introduce a corporate network and a corporate approach to the need for communications, to introduce services giving a substantial fast payback, to introduce services that reduce reliance on specific suppliers, and to identify services that are required to meet business objectives.

## MAS Bulletins

The following Military Applications Summary (MAS) Bulletins were published between 10 April and 8 September 1989. The MAS Bulletin is an account of accomplishments in European naval research, development, and evaluation. Request copies of the Bulletins, by number, from ONREUR.

- 33-89 Portable, Pneumatic Machining Units
- 34-89 Space Highlights - 1989 Paris Air Show
- 35-89 European Hypersonic Technology Programs Update
- 36-89 French Spaceplane - HERMES Update
- 37-89 Antisubmarine Warfare Area System
- 38-89 Second Generation Night Observatopm Device
- 39-89 Twin 30 Compact Naval Mount
- 40-89 GY-90 Fiber Optic Gyro
- 41-89 Rescue Stretcher
- 42-89 Second Generation Crewserved and Individual Served Weaponsights
- 43-89 Aquamesh Fiber-Optic Alarmed Underwater Security Barrier
- 44-89 MW 08 Multi-Beam Air and Surface Surveillance Radar
- 45-89 High Performance Electro-luminescent Memory Display
- 46-89 Strip Laminate Rocket Motor Cases

## Reports on European Science and Technology from Other Commands

### Reports

Information on each of the reports listed below was furnished by the following activity. Requests for copies of or information about the document should be addressed to:

**EOARD** - European Office of Aerospace Research and Development, Box 14, FPO New York 09510-0200.

### Acoustics

*SEP Ceramic Matrix Composites for Hermes*, by LTC James G.R. Hansen, EOARD. (23 pp) [EOARD/89-045]

Hermes, the European Space Plane, will make extensive use of C/SiC and SiC/SiC ceramic matrix composites. The preferred material consists of carbon fibres reinforcing a silicon carbide matrix. The Hermes vertical fins could soon be the world's most advanced hot primary structure for a hypersonic vehicle. Other CMC components include thermomechanical protection shingles, the nose cap, and elevons.

### Biotechnology

*Biotechnology and HEDM-related Research at CNRS in France*, by LTC Chet Dymek, EOARD. (25 pp) [EOARD-LR-89-046]

Research related to two AFOSR initiatives is being done by groups from two CNRS laboratories, Dr. Maryse Lenfant's group at the Institut de Chimie des Substances Naturelles (ICSN) at Gif sur Yvette, and Dr. Claude Paillard's group at the Centre de Recherches sur la Chimie de la Combustion et des Hautes Temperatures (CRCCHT) at Orleans. The main interests of Dr. Lenfant's group of 14 are regulators in mammalian cell proliferation and bioconversion of organic nitro compounds. Dr. Lenfant has demonstrated high yield conversion of polynitrates to mononitrates using various microbes. At the CRCCHT, Dr. Paillard leads a group of 10 studying gas phase explosions and high temperature chemical kinetics of highly energetic compounds. Of particular interest is Dr. Paillard's work in azide decomposition kinetics.

### Computer Science

*University of Newcastle-Upon-Tyne, U.K., Computer Science and Electrical Engineering Departments*, by MAJ Parris Neal, EOARD. (5 pp) [EOARD-LR-89-044/5pp/Neal/4526]

The University of Newcastle Department of Computer Sciences has been involved for many years in the problem area of intercomputer communications. A system for

UNIX-based communications called the "Newcastle Link" was developed here and is now available as a commercial package. Work is now going on for heterogeneous computer systems to communicate. Additionally, extensive work is being done on fault tolerant systems, distributed processor systems, and shared memory parallel computers using the Encore Computer for in-house development. The Department of Electrical Engineering works closely with the Computer Science Department and develops VLSI hardware systems. These hardware platforms are designed with fault tolerance and self-correcting algorithms right in the chip. Another area of interest lies in the development of the electro-magnetic theory associated with mm wave scattering through particulate contaminated atmosphere using single particles in an open microwave resonator. Digital adaptive communication techniques are being investigated to develop an underwater acoustical communication link. This secure link is intended to provide high data rates, low error rate, and resistance to multipath--all without using umbilical cables.

### Electronics

*Research and Testing Within the Italian Air Force*, by MAJ Parris Neal, EOARD. (4 pp) [EOARD-LR-89-037]

The Divisioni Aerea Studi Ricerche e Sperimentazioni (DASRS) is the consolidated research organization of the Italian Air Force. This relatively new facility is located just outside Rome at the Aeroporta Pratica de Mare. All Italian Air Force flight testing, including the multinational Tornado test program, is conducted by DASRS. Additionally, Italian military space projects, nondestructive testing of aerospace materials and systems, armament systems testing and integration, and aerospace medicine are conducted by this group.

*FIAR--Fabbrica Italiana Apparecchiature Radioelettriche, SpA, Milan, Italy*, by Dr. Vince Donlan, EOARD. (19 pp) [EOARD-LR-89-038]

The FIAR develops and produces systems and subsystems for use in space, robotics, artificial intelligence, information processing, environmental control and surveillance, and electronics. This report describes research FIAR is doing in several of these areas. This research includes mm wave satellite-to-satellite communications, diode-pumped Nd-YAG lasers for space communications and laser radars, CO2 laser vibration detection, gaussian reflectivity profile laser mirrors, power conditioners and power supplies for electric pro-

pulsion, GaAs/Ge solar cells, advanced robotics, and expert systems.

*The Nardi Company*, Milan, Italy, by Dr. Vince Donlan, EOARD. (6 pp) [EOARD-LR-89-040]

The Nardi Company's Aeronautical Components Division in Milan and the Electronic Systems Division in Aprilia are discussed in this report. Several of the company's advanced products and research and development programs are described briefly, including flight control for KE weapons, advanced composites in landing gear and integrated fly-by-wire control systems, integrated hydraulic systems, fly-by-light, FLIR receiver, and battle-field C3 sensor fusion/correlation system.

#### Fluid Mechanics

*Fluid Mechanics Research at Chalmers Institute of Technology*, by LTC Fred Gilliam, EOARD. (7 pp) [EOARD-LR-89-052]

The Department of Thermodynamics and Fluid Mechanics at Chalmers Institute of Technology in Göteborg, Sweden, has an active and diversified research program in fluid mechanics. Their work in turbulent boundary layer structures, led by Drs. Gunnar Johansson and Lennart Lofdahl, has investigated boundary layer structures and identified higher order mixed moments in regions very near the wall. This report describes that work along with research on advanced turbulent boundary layer instrumentation, pressurized fluidized bed combustion, and several other topics.

#### Life Sciences

*Metabolism and Toxicity of Hydrazine*, by MAJ Jim McDougal, EOARD. (5 pp) [EOARD-LR-89-048]

Dr Timbrell, University of London, School of Pharmacy, has made excellent progress during the first 6

months with his grant entitled "Studies on the Metabolism and Toxicity of Hydrazine" (AFOSR 88-0015). Dr Timbrell and at least two graduate students have been working on the project. During this time, they have modified three assays for hydrazine, investigated the *in vitro* disappearance of hydrazine (Hz) from rat liver microsomes and cultured hepatocytes, investigated hepatic toxicity *in vivo*, and identified some new urinary metabolites in the rat.

#### Physics

*Laser Research at the Istituto Nazionale Di Ottica, Florence, Italy*, by Dr. Stacey Lazdinis, EOARD. (9 pp) [EOARD-LR-89-039]

The research being performed in Deterministic Chaos at the Istituto Nazionale di Ottica in Florence, Italy, is summarized. The theoretical and experimental investigations of Drs. Arecchi, Meucci, Ciliberto, and Salieri dealing with the transition to Chaos in Quantum Optical systems, such as CO<sub>2</sub> lasers, and in Rayleigh-Benard Convection are detailed.

#### Semiconductors

*Paul Scherrer Institute/RCA Zurich Laboratory*, by Dr. Eirug Davies, EOARD. (4 pp) [EOARD-89-035]

This former RCA Laboratory is now part of a national institute and is assuming its new role of assisting Swiss industry. Its traditional strengths were in silicon technology and optical characterization which are being redirected into GaAs processing and optical components. The optical work ranges from diffraction grating studies to nonlinearity in KNbO<sub>3</sub> and passive guides in evaporated TiO<sub>2</sub>/SiO<sub>2</sub> structures.

## THE EMBASSIES: TECHNOLOGY ROUNDUP

### Federal Republic of Germany

*For further information on FRG items, contact Mr. Edward M. Malloy, Science Counselor, American Embassy, Bonn, APO New York 09080-7400.*

#### Research and Development in the Federal Republic of Germany's Microelectronics Industry

The Federal Republic of Germany's (FRG) government has undertaken a broad program of support for research and development (R&D) in microelectronics. Carried out in cooperation with leading industrial firms, research institutes, and universities, the goal of this research is to gain a competitive footing in the global competition to develop and manufacture microelectronic

chips. Production capability in this area is viewed as necessary for entry into the \$500 billion-a-year information technology market. The research effort is being developed regionally through European Community (EC) programs such as the European Strategic Program for Research and Development in Information Technologies (ESPRIT), R&D in Advanced Communications Technologies in Europe (RACE), and the European Research Coordination Agency (EUREKA) program (Ion Lithography and Jessi). Currently, Western Europe produces only 10 percent of the world chip production, compared with 47 percent for Japan and 41 percent for the U.S. Many observers believe that this gap will widen without a concerted government-supported European-wide effort.

The microelectronics industry in the FRG, with sales of just over \$2 billion, represents less than one-half of one percent of the total industrial output. Microelectronics represents a key element not only in the electronics industry but more importantly to the FRG's five largest export-oriented industrial sectors--motor vehicles, mechanical engineering, electrical engineering, precision mechanics, and data processing. These five groups provide about three million jobs and 47 percent of the FRG's exports. By 2000, the consumption of microelectronic elements is expected to be nearly \$200 billion annually.

Currently, FRG microelectronics production capacity amounts to just 40 percent of domestic consumption; 60 percent is provided by overseas suppliers. In the view of some government planners, this reflects a high and potentially precarious dependence on U.S. and Japanese suppliers. By 2000, FRG planners hope that the country's industry will be able to supply 100 percent of domestic consumption in microelectronics. To reach this goal, FRG industry must spend more than \$12 billion on R&D and \$8 billion on capital investment to expand production capacities. Another dependency lies in manufacturing equipment and test facilities for microelectronic chip development and production. Here, too, the FRG relies on the U.S. and Japan for 90 percent of this equipment. The FRG microelectronics industry seeks assistance from its government in funding high risk research.

From 1984 through 1988, the Federal Ministry for Research and Technology (BMFT) has spent about DM 1.1 billion (\$530 million) in direct project support for microelectronics research. The BMFT has funded about 150 projects, over half of which (DM 570 million or \$325 million) were carried out by industrial firms. Five major firms took a lead in 42 projects costing DM 490 million (\$280 million), or nearly one-half of the total BMFT budget for microelectronics R&D. Heading the list is Siemens with 13 projects valued at DM 300 million (\$171.5 million), followed closely by Philips, AEG, Telefunken Electronics, and ALCATEL/SEL.

The FRG's microelectronics promotion policy focuses on the support of R&D activities in the fields of

- Computer-aided design (CAD) of integrated circuits (IC) and training of informatics engineers
- Advancement of submicron technology
- Enhancement of gallium-arsenide (GaAs) technology.

In the field of CAD of IC's, research efforts concentrate on the development of enhanced techniques for the short-term and cost-efficient development of very large scale integrated (VLSI) circuits. Joint projects involve 26 universities, two Fraunhofer institutes, the large-scale research facility GMD and the research laboratories of the industrial enterprises Siemens and AEG. Because of the serious shortage of informatics and electronics engineers,

the FRG's promotion program includes long-term measures to overcome the estimated shortfall of 40,000 trained informatics engineers through 2030. Among these measures are creating new places for study at the universities, improving equipment at university laboratories, and providing university institutes with computer work stations.

The program in submicron technology focuses on two major topics:

- Advanced development of X-ray lithography and etching technology
- Advanced development of the future megabit chip generations, including CAD techniques, and the appropriate process and production technologies.

Among the leading research institutes involved are the Fraunhofer Institute for Microstructure Technology in Berlin or the Berlin Electron Storage Ring for Synchrotron Radiation (BESSY) both of which work in close cooperation with industrial firms. The development of the megabit chip technology is predominantly done through a joint collaborative project between Siemens and Philips, with Siemens developing the 4-Mbit dynamic RAM (DRAM) and Philips, separately developing the 1-Mbit static RAM (SRAM) technology, with a close exchange of information during the development processes.

The third objective of the FRG's microelectronics promotion on policy focuses on the enhancement of the GaAs technology. The priority in R&D efforts is in production technologies of GaAs substrate materials of the highest purity and the development of innovative heterogeneous semiconductor components.

Approximately 50 research institutes, university institutes, and industrial enterprises currently perform research in the field of microelectronics. Among these 50, the leading institutes are the German Large-Scale Research Facility of Mathematics and Data Processing (GMD) in Bonn; the Fraunhofer institutes in Berlin, Freiburg and Duisburg conducting research on microstructure technology, microelectronic system development, and new materials; the Heinrich-Hertz-Institute in Berlin and some Max-Planck-Institutes focusing on basic research in microelectronics technology. Industrial research is predominantly performed in company-owned laboratories by a few large firms, such as Siemens, Philips, Telefunken, AEG, ALCATEL/Standard Electronic Lorenz. They seek to develop in their laboratories advanced chip generation, along with the appropriate production process technology. Also being developed are enhanced designs and system technology, the development of application-specific integrated circuits (ASIC), and the improvement of the GaAs technology.

Concerned with future market share worldwide and with an eye to the 1992 single market exercise, German and other European microelectronics and information

technology companies have intensified their cooperation and mutual consultation. International cooperation in precompetitive phases of R&D has been underway for several years in the framework of ESPRIT and RACE programs and the EUREKA initiative. Acting upon the initiative of the EC commission, the 12 major European microelectronics and information technology firms in the FRG (Siemens, AEG, Nixdorf Computers), France (ALCATEL, Thompson, Bull), the Netherlands (Philips), Great Britain (GEC, Plessey, ST/ICL), and Italy (Olivetti, STET) have recently formed a "round table" group. This "round table" facilitates high-level executive consultations and discussions of joint market strategies. Working with the EC commission, the firms are better able to make decisions on the launching of new community R&D programs and obtain the political support necessary for their implementation.

#### Microsystem Technology Research in Berlin

In 1983, the "Fraunhofer-Institut Fuer Mikrostruktur-technik" (IMT) spun off from the Munich-based Fraunhofer Institute for solid state technology. In 1986, the IMT moved into a new building and is now one of two Fraunhofer institutes based in Berlin. The other one is the Fraunhofer Institute for Production Facilities and Construction Technic (IPK). Similar to other Fraunhofer institutes, contracts with private companies cover 70 to 80 percent of the operating costs (DM 19 million in 1988) of the IMT. The building that houses the IMT is financed through special federal/city arrangements, while the Federal Ministry of Research and Development pays for the IMT's equipment, most of which was made in the U.S. About 130 staff members, of whom 50 are scientists, as well as 20 representatives of affiliated companies are working at the IMT.

The IMT's research emphasizes high-resolution lithography methods (in particular, X-ray lithography) and etching techniques for resist pattern transfers. The IMT also researches pre-use testing of developed single processes on VLSI circuits in a submicrometer laboratory line. Moreover, the IMT develops fundamentals for future technologies subsequent to the 1-micrometer technology.

The IMT does contract research for German semiconductor producers Siemens, Telefunken, Valvo, and Eurolsil. The IMT is examining possibilities for a complete submicrometer process line by using highly integrated structures. The IMT also coordinates the work of the German "Joint Project on Sub-Micron Technology" and the working group "X-ray Lithography" which focus on R&D of submicron technology for the fabrication of highly integrated circuits from silicon. The technologies tested as supposed to be employed in future generations of VLSI devices.

The IMT has developed a silicon technology used in micromechanics by which miniature three-dimensional mechanical structures are produced through selective etching techniques and X-ray depth lithography in the silicon crystal. This application is intended to be used mainly in sensor and actuator technologies.

The BESSY, located in a building adjacent to the IMT, delivers the synchrotron radiation necessary for IMT's operations. (Synchrotron radiation has a shorter wavelength than visible light and permits the transfer of much smaller patterns than does optical lithography.) An additional radiation source, compact storage ring (COSY), designed specifically to produce synchrotron radiation.

#### France

*For further information on France items, contact Dr. Allen Sessoms, Science Counselor, American Embassy, Paris, APO New York 09777.*

#### French Research and its Relationship to the French Economy

Public research expenditures compared with the general domestic product (GDP) are higher in France than in other industrialized countries. The difference in the level of industrial research is thereby accentuated. Further, industrial research focuses on a few sectors. In spite of the measures taken to remedy this situation, the gap between public and industrial research has not been reduced. Between 1981 and 1987, most export/import ratios for high technology products have decreased. This suggests that insufficient research has translated itself into a lack of technical competitiveness for certain industrial products.

The analysis of the industrial structure has similar implications. There are sectors where the favorable situation of France is because of intense research activities financed by the French government, such as in space, civilian aeronautics, and nuclear-related. However, most industrial sectors do not do so well. Fundamental research is of high quality. The main deficiency is in basic technological research, especially collective research. (Collective research in France is research shared among several industrial companies).

In spite of the increase in technology transfer institutions, industrial demand remains low and the importance of technology not fully acknowledged. One of the major problems confronting French industry is that of research personnel (turnover and training). The increasing average age of research personnel, mostly because of stop/go recruitment policies, dampens the dynamism of French research. Further, France has a scientific rather than a technological culture. To change this, engineering schools must conduct more research and universities

become more technology oriented. Training to and through research must be extended.

### Research in France

Because of insufficient financial and human research resources in 1986, French research and development (R&D) effort ranked fourth after the U.S., Japan, and the Federal Republic of Germany (FRG) and came just before that of the U.K. The domestic R&D expenditure/GDP ratio is only 2.3 percent in France, against 2.8 percent for the U.S. and Japan, 2.7 percent for the FRG and 2.4 percent for the U.K. Public financing of R&D in France, compared with the GDP, is the highest of all Organization for Economic Cooperation and Development (OECD) countries. The civilian R&D budget will exceed F42 billion (\$6.3 billion) in 1989. Military R&D expenditure is estimated at F31 billion (\$4.6 billion). Total R&D expenses financed by the French government will exceed F80 billion (\$12 billion) exclusive of tax incentives.

Financing by companies relative to the GDP is half that of the FRG, one third that of Japan, one tenth that of the U.S. The French Research Ministry considers that French industrial research is short of F25 billion (\$3.7 billion) each year. In 1987, R&D carried out by French corporations amounted to F70.9 billion (\$10.6 billion). French companies' share in such expenses was 69 percent. Public entities contributed 23 percent (approximately F16.2 billion - \$2.4 billion) in the form of contracts or subsidies; the remaining comes from abroad or from international organizations. Two-thirds of the public contribution comes from the Ministry of Defense. The remaining one third is essentially for civilian aeronautics and communications development programs.

France is also behind other countries with respect to the number of research personnel. In 1985, there were 4.5 researchers per 2,000 actively engaged people, against 5.2 in the FRG and 6.5 in the U.S. The gap is even wider in industry: 6 researchers or research engineers per 1,000 actively engaged persons in France against 8 to 10 in the FRG.

### Fundamental Research

Research is conducted in France by universities and by public institutions, such as Centre National De La Recherche Scientifique - National Center for Scientific Research (CNRS), Commissariat A L'Energie Atomique-Atomic Energy Commission (CEA), Institut National De La Sante Et De La Recherche Medicale-National Institute for Health and Medical Research (INSERM), Institut National Pour La Recherche Agronomique-National Institute for Agronomic Research (INRA), and semipublic institutions such as the Pasteur and Curie Institutes.

The total 1989 budget for scientific research amounts to F25,823 million (\$3,854 million). This budget does not include regional contributions or laboratory receipts. One third of the budget goes to university research (F9.6 billion [\$1.4 billion]), which is equivalent to what CNRS receives (F9.5 billion) as well as the other research institutions (mainly INSERM and INRA) taken as a whole.

France's fundamental research is high quality in nearly all sectors with a few areas of excellence; e.g., AIDS and identification of oncogenes. One of its strong points is mathematics. Indexes show that France ranks fifth among OECD countries for the number of its scientific publications with nearly 7 percent of the total.

However, basic technical research is not going so well. Only 7 to 8 percent of the budget is allocated to such research against 13 percent in the FRG. France's technical basic research is high quality in such disciplines as metallurgy and chemical engineering. It is weaker in other areas such as material sciences.

The major difference between France's research policy and that of its main partners is that evaluation is insufficient. Fundamental research is partially subject to review. However, management requirements and program objectives are often mixed. This has led to a system where choices are not made and the best employees not always promoted.

Universities house some 44,000 faculty, and 10,000 engineers; technical and administrative staff collaborate with them in 4,000 laboratories located in some 160 higher education establishments. Sixty percent of CNRS research personnel work in university laboratories associated with CNRS. Likewise, numerous INSERM units are located on university premises. More recently, INRA has started to associate with university teams. Conversely, 2,700 full-time equivalent faculty carry out their research in CNRS units.

Out of F9.5 billion (\$1.4 billion) for university research, only F1.55 billion (\$23,134 million) is for infrastructure, maintenance, and laboratory operations, while 84 percent is for salaries. In view of this, it is clear that university laboratories could not conduct research if they were not associated with CNRS or INSERM.

In fact, CNRS has been gaining influence on university orientations and activities. Besides, the university system is becoming blocked not only because of inefficient, cumbersome, and nonmotivating university structures but also because of a bureaucratic and intrusive ministerial authority. There remains little room for the definition of a higher education policy.

The largest public research institution is CNRS, a multiplinary establishment. There are 10,000 researchers, 15,000 engineers, and technical and administrative staff who work in its 300 laboratories and in the 900 research units associated to CNRS. Its 1989 budget is F9,662 million (\$1,442 million), which represents a 7.9

percent increase over 1988. Salaries account for 71 percent of the budget; only 29 percent is therefore left for actual research operations. This low figure makes it extremely difficult to use resources efficiently.

#### Applied Research in Public Research Institutions

One of France's distinguishing features is that it has powerful applied research establishments. The most important are Commissariat A L'Energie Atomique-Atomic Energy Commission (CEA), Centre National d'Etudes Spatiales-National Center for Space Research (CNES), and Institut Francais de Recherche Pour l'Exploitation de La Mer-French Research Institute for Sea Exploitation (CNES). They are concerned with strategic areas and major technological programs; e.g., nuclear, space, and ocean engineering. France's performance in these areas is particularly good.

#### Military Research

Twenty percent of the total budget for armed forces equipment is for R&D. In 1989, the defense R&D budget will amount to F31 billion (\$4.6 billion) and represent one-third of the total public R&D funds and more than half of those allocated to companies. The rapid growth of the R&D budget, which was much faster than that of the full defense budget, shows the impact of new technologies on armament systems.

The countries that allocate the most resources to military research are the U.S. and the U.K., followed by France. Three-fourths of public U.S. R&D expenses, half of British expenses, and one-third of French expenses are for defense.

In the military R&D budget, the nuclear sector ranges between 35 and 40 percent. Space programs have also significantly increased in the past 2 years (F2.4 billion [\$358,209] in 1988, 45 percent more in 1989). Research is principally conducted by large corporations and to a lesser extent by organizations coming under the defense ministry.

The distribution by sectors of R&D funds allocated to industry is as follows:

- Aerospace and missiles (exclusive of nuclear warheads): 40 percent
- Electronics-data processing: 30 percent
- Ground armament: 11 percent
- Nuclear (exclusive of CEA): 6 percent
- Sea armament: 6 percent
- Other sectors: 7 percent.

In 1985, the defense ministry contributed 12 percent of companies' R&D budget. The funds were principally concentrated on aeronautics (42 percent of the R&D budget of the sector) and electronics (19 percent)

#### Industrial Research

Since 1979, companies' R&D expenses have increased by 4.8 percent per year; that is more than Germany (3.7 percent) and the U.K. (2.7 percent), but less than the U.S. (6.2 percent) and Japan (10.4 percent). However, this increase has not permitted them to catch up with the ground lost by French industry between the two oil crises. The gap between France and its main competitors is even wider for civilian research. In 1985, while the company financing/GDP ratio was 2.18 percent in Japan, 1.53 in the FRG, 1.4 in the U.S., and 1.09 in the U.K., it was only 0.84 in France.

The French government civilian R&D expenditures equalled 1.01 percent of the GDP in 1985 compared to 1.0 percent in the FRG, 0.62 percent in the U.K., 0.57 percent in Japan, and 0.41 percent in the U.S. Therefore, the French government finances a greater percentage of industrial R&D than other OECD countries. Although French companies invest too little in R&D, the exception is the military sector. French industrial R&D ranks fifth among OECD countries. However, French R&D potential is concentrated in a few sectors. Six areas--electronics (22 percent), aeronautics (18 percent), automobile (10 percent), chemistry (10 percent), pharmacy (7 percent), and energy (6 percent) amount to three-fourths of companies' R&D expenditure, while they contribute only one-fourth of the industry added-value. Conversely, other industries, which contribute more to the GDP, conduct little research (agrobusiness, metallurgy, textile). Most small- to medium-sized companies are in the same situation.

The distribution of public funds is even more uneven. The major part goes to aeronautics and electronics. The government finances half of R&D in aeronautics and over one-third in electronics. These subsidies correspond to 46 percent and 37 percent, respectively, of the governmental contribution to company research. This policy encourages achievement of program objectives rather than industrial competitiveness on markets. In 1986, 140,000 full-time equivalent persons, of whom 45,000 were researchers, participated in industrial R&D. This figure is lower than France's competitors. More than 60 percent of the 140,000 persons work in 187 companies, each employing more than 2,000 persons. These large corporations conduct nearly 70 percent of the research and receive 85 percent of public funds. There are more researchers in the sectors supported by the government.

R&D in large French corporations is at a level comparable to that of their foreign competitors. Other companies conduct less research on average.

## Italy

*For further information on Italian items, contact Gerald Whitman, Office of Science Counselor, American Embassy, Rome, APO New York 09794-9500.*

### 1988 Trends in Italian Science and Technology

**Introduction.** This report highlights the science and technology (S&T) trends in Italy during 1988. The information was taken primarily from the Italian National Research Council's Annual Report as well as on other data available to the embassy.

In 1988, Italy made substantial progress in strengthening its organizational infrastructure for scientific research, establishing a new space agency and expanding the role of the Ministry of Scientific Research (MRST) to include research and budget coordination for the universities and science agencies. The government also continued efforts to improve links between universities and industry, and to streamline the Italian National Research Council (CNR) bureaucracy through consolidation of its institutes.

Italian research expenditures for 1988 increased by 9 percent in real terms over the previous year to about \$11.5 billion. Most of the increase was in the public sector which for the first time surpassed the private sector in overall expenditures. The CNR and the Italian universities received large increases. The budget for Nuclear and Alternate Agency (ENEA) received a modest increase, reflecting successful efforts to shift from nuclear to alternate energies and technology development.

Even with the spending increases, Italy spent only about 1.4 percent of gross national product (GNP) on research and development (R&D), about half that of the other major Organization for Economic Cooperation and Development (OECD) countries. Efforts to increase S&T resources are impeded by the large public deficit and a shortage of scientists and support personnel to carry out research. Italian universities are unable to meet the growing demand for scientists and engineers and the shortage may worsen as the 1992 unified market creates new opportunities for Italian scientists to work in better equipped laboratories at higher salaries.

**1988 Achievements.** CNR President, Luigi Rossi Bernardi, in his yearly address on the status of scientific research in Italy, enumerated some of Italy's scientific achievements in 1988. The Italians

- Commenced the installation of experiments at the underground high energy physics laboratory at Gran Sasso
- Completed a third antarctic expedition, with research in biology, telemedicine, oceanography, atmospheric physics, and environmental and earth sciences

- Initiated a "strategic project" on human genome sequencing under Professor Renato Dulbecco
- Initiated "ICAROS," a joint project with CNR and SORIN to build an artificial heart
- Completed the first phase of "OSIRIDE," a program for the standardization and interconnection of different computerized systems
- Commenced construction of the synchrotron light source in Trieste
- Inaugurated the southern section of the National Institute of Nuclear Physics in Catania and the research area in Milan
- Completed site preparation in Padua for the reverse field experiment (RFX) nuclear fusion research project
- Successfully linked chromosome 21 of the human genome as causing Alzheimer's Disease.

The government also made significant achievements in streamlining and restructuring Italy's scientific bureaucracy. Parliament

- Created an Italian Space Agency ASI (Agenzia Spaziale Italiana)
- Approved the draft law giving the Ministry for Scientific Research responsibility for the universities and budget coordination for the science agencies
- Approved the creation of the National Center for Aerospace Research (CIRA) to be located near Naples.

**Italian S&T Resources for 1988.** Overall research expenditures in Italy for 1988 were estimated at 15,594 billion lire (about \$11.5 billion), a real increase of 9 percent over 1987. Expenditures in terms of percentage of GNP remained at 1.4 percent. (GNP increased 3.9 percent in 1988.) The rate of increase in research expenditures declined from the 18 percent registered between 1986 and 1987. Research and development (R&D) funding 1980-88 is shown in Table 1.

About 122,352 persons were employed in R&D in Italy in 1988 (full-time equivalents). Of these, 67,000 were researchers, 32,000 were technicians, and 21,000 were in administration. The increase in personnel for the last 6 years averaged 4.2 percent. The number of researchers for 1980-88 is given in Table 1.

**Table 1. Funding and Personnel Resources for R&D**

Year	Expend. (billions of lire)	% GNP	Researchers
1980	2,897	.74	46,999
1981	4,055	.87	52,060
1982	4,915	.90	56,707
1983	6,027	.95	63,021
1984	7,323	1.0	61,979
1985	9,133	1.1	63,759
1986	10,189	1.1	67,844
1987	13,669	1.4	-
1988	15,594	1.4	67,000



A comparison of Italian science indicators with some other OECD countries is given in Table 2. In 1986, Italy spent only 1.3 percent of GNP on R&D, compared with 2.8 percent for the U.S. and Japan, 2.7 percent for the Federal Republic of Germany, 2.4 percent for the U.K., and 2.3 percent for France. The percentages improve somewhat when defense spending is factored out, since Italy spends only about 8 percent of total R&D expenditures on defense. Because the number of researchers in Italy is considerably less than the other OECD countries, the Italians compare favorably in funds available per researcher (second highest in the OECD).

**Table 2. Science Indicators in Some OECD Countries**

	U.S.	Japan	FRG	U.K.	FR	Italy
Total R&D expend. (billion \$)	117	42	22	16	15	8.1
Expend as PCT GNP	2.8	2.8	2.7	2.4	2.3	1.3
Civil R&D PCT GNP (1985)	1.9	2.6	2.4	1.6	1.7	1.1
Researchers (1,000)(1985)	762	473	144	94	102	64
\$/researcher (\$ x 1,000)	154	89	153	170	147	127

NOTE: All data is 1986 unless otherwise indicated.

The breakdown of 1988 research expenditures by sector is shown in Table 3. Public sector spending for the first time surpassed the private sector in 1988 increasing 14 percent in real terms. Private sector financing increased a mere 3 percent, a remarkable slowdown after the 30 percent increase the year before. Of this, only 2 percent was attributed to private industry, while partly state owned industry had an estimated growth of 5.4 percent over 1987.

In the public sector, university expenditures increased 23.6 percent over 1987 to 2,780 billion lire. The largest government research agency, CNR, posted a 17.2 percent increase over 1987 to 1,452 billion lire. The ENEA's budget, which plummeted 18 percent in 1987 following an antinuclear referendum, rebounded with an 11.7 percent increase, reflecting ENEA's success at reorienting its activities away from nuclear toward alternate energies and technology development. Elsewhere, the ministry of defense received a 73.6 percent increase in its research budget, and the ministry of agriculture increased its budget by 19.2 percent.

The CNR budget includes 1,400 billion lire for research (33 percent increase), 400 billion lire for personnel (22 percent increase), and 194 billion lire for research support (20 percent increase). An additional 380 billion lire is included for space research that in 1989 will be managed by the new Italian Space Agency, plus about 200 billion lire for special finalized projects.

**Table 3. Research Expenditures by Sectors**

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	Lire billions	\$	%
Universities	2,776	2,135	34.5
CNR	1,452	1,117	18.1
ENEA	944	726	11.7
Defense	906	697	11.3
INFN	243	187	3.0
Inst. of Health	128	98	1.6
Agric. Ministry	69	53	.9
Other Ministries	204	157	
Regions	28	22	.3
Int'l Contribution	517	398	6.4
Other	<u>777</u>	<u>598</u>	<u>9.7</u>
Total	8,044	6,188	100.00

In 1988, CNR started 10 new "third generation" finalized projects: building technologies, electronics, superconducting and cryogenic technologies, robotics, new materials, informatics systems, internationalization (i.e., competitiveness) of industries, biotechnologies, telecommunications, and fine chemicals.

The ENEA is the principal Italian agency for advanced technology development, supporting technology transfer to Italian industry, coordinating Italian participation in European Research Coordination Agency (EUREKA), and conducting studies for radio protection applications of nuclear energy for nonenergy uses. The ENEA's 1988 budget (944 billion lire) includes 324 billion lire for nuclear research, primarily for fusion research and the transfer of nuclear plant building technology to conventional plants. Other areas of research include renewable energies, energy saving, environmental protection studies, and research in agriculture and biology.

A breakdown of R&D financing and execution is shown in Table 4. About 42 percent of R&D financing is provided by the state while state institutions carried out

**Table 4. R&D Financing and Execution**

	1988	
	Financing %	Execution %
State	42.1	-
Nat'l laboratories	-	13.9
Universities	-	19.7
Public enterprises	12.7	22.2
Private enterprises	27.6	36.2
Foreign	4.4	-
Other	<u>13.2</u>	<u>8.0</u>
Total	100.0	100.0

only about 34 percent of R&D. As in previous years, the balance financed research in public and private enterprises. A new category this year is foreign financing, which accounts for 4 percent of the total.

The Italian contribution to European Research Programs increased 47.3 percent, representing 6.9 percent of the total European expenditure. Most of the contributions went to the European Space Agency.

When compared to the other OECD countries, Italy spends proportionally more on industrial research, energy and space, and less on defense and infrastructure R&D. These figures are shown in Table 5.

**Table 5. R&D Expenditures by Sector**

	1987					
	Italy	FR	FRG	Japan	U.K.	U.S.
Basic Research	38.5	26.7	43.8	54.7	20.2	3.6
Energy	11.1	6.7	8.7	14	3.5	3.6
Industry	19.1	10.6	15.3	5.1	8.7	.2
Defense	7.8	34.1	12.5	2.8	50.3	68.6
Health	5.7	6.3	5.5	3.2	5.8	12.9
Space	9.3	5.9	4.9	4.4	2.7	6.0
Agriculture	3.5	3.6	2.0	10.9	4.2	1.9
Infrastructure	.8	3.2	1.9	1.4	1.5	1.8
Environment	.9	.4	3.3	2.5	1.0	.5

**Trends and Problem Areas.** Italy's objective of reaching parity in 1992 with the other European countries in terms of percentage of GNP for S&T development is being impeded by chronically high national budget deficits. To compensate for possible cuts in science spending, CNR president Rossi Bernardi proposes that Italy concentrate on the research sectors where it already is advanced; e.g., high energy physics, solid state physics, molecular biology, biotechnology, and fine chemicals. Officially, reaction to the proposal is warm, but we expect there will be strong resistance from those in other research areas whose budget would be cut.

Another significant problem in increasing R&D is Italy's relatively small number of researchers--about 67,000--the least of any major OECD country. In addition, the number of researchers working in "strategic sectors" contributing to economic and industrial development is estimated at 30,000. A study projecting requirements through 1992 indicates there will be 2,400 unfilled research positions if research expenditures reach 1.9 percent of GNP. The GNP increases to 13,000 if research expenditures rise to 2.1 percent of GNP.

The Italians thus far have been unsuccessful in increasing the flow of university science and engineering graduates. According to ministry of public instruction statistics, only 24 percent of Italian youths between ages

18 and 24 enroll in the university, far below the rest of Europe and the U.S. (Worldwide, Italy is 25th in the number of university student enrollment.) Of these, only 30 percent graduate compared with 80 percent in the U.K., 68/70 percent in France and 50 percent in the FRG. The output of graduates in industrially developed regions like Piedmont and Lombardy is enough to cover only 50 percent of industry demand, which is greatest for engineers, chemists, economists, physicists, and computer specialists.

There is also strong competition between university and industry for new scientists and engineers. Many Italian industries, such as Olivetti, Pirelli and Fiat are attracting students by awarding fellowships and grants in exchange for a commitment to join the industry after graduation. Olivetti last year alone sponsored more than 100 graduates. Bulletin boards in northern universities are filled with announcements for fellowships and grants that often remain unanswered. One electronic engineer graduate from the Milan Polytechnic said he received no less than 40 employment proposals during his last 2 years at the university. To fill the growing gap, many Italian industries are looking for talent in Switzerland, FRG, France, and the U.S.

Another problem impeding S&T growth is the ossified personnel system for researchers. Italy has the highest number of any OECD country of "lifetime researchers" resulting in molasses-like promotion and a bottleneck for hiring new and younger personnel. The Italians are worried that the 1992 unified market and resultant labor mobility may cause a "brain drain" from Italy to other European countries with better equipped laboratories and higher paying positions. An experiment to improve personnel mobility is being implemented, against union opposition, at the new Italian Space Agency where researchers will be hired under time-limited contracts.

Italian officials hope that many of these problems will be resolved with the transfer of university education from the Ministry of Public Instruction (MRSI) to the Ministry of Scientific and Technological Research (MRST). The universities under the MRST are given unprecedented autonomy. Each university may establish its own courses, create different types of degrees and specializations, set up research programs, and allocate funds without going through complicated and lengthy bureaucratic channels as had been required in the past. The National University Council, an advisory body to the Ministry for University Matters, will also be reorganized, and a new National Council of Science and Technology will be created.

## Portugal

*For further information on Portugal items, contact the American Embassy, Lisbon, Avenida das Forças Armadas, 1600 Lisbon, APO NY 09678-5320.*

### Portugal: AIDS Update

The number of diagnosed cases of AIDS in Portugal continues to rise, albeit at a comparatively modest pace. The official Government of Portugal (GOP) AIDS task force reported that, as of the first quarter of 1989, there were 224 diagnosed cases, up from the last reported total of 67. There have been 114 AIDS-related deaths in Portugal since the government first began tracking the disease in 1983. Homosexuals still remain the largest risk group, accounting for 48 percent of the cases, and are followed by heterosexuals, who account for 17 percent of those affected. As of the end of 1988, 19 AIDS victims carried the HIV-II virus, which has begun to appear with greater frequency in Portugal among detected HIV seropositives in the last 2 years. This phenomenon is attributed to the greater interaction between segments of the Portuguese population and individuals either from or traveling to the former Portuguese West African colonies, Guinea-Bissau, and Cape Verde. As a result, the GOP is preparing legislation requiring HIV-II blood testing of donated blood. Similar legislation for HIV-I already is in place. While concern for AIDS remains high in the Por-

tuguese government, the media, the medical community, and the general population, there is no undue alarm, and efforts to educate the public continue (young people in particular).

Largely because of the efforts of the GOP AIDS task force, headed by Dr. Laura Ayres, knowledge of AIDS in Portugal is probably on par with that of most other developed countries. Although few in number, laboratories and hospitals are reasonably equipped to deal with the still relatively few cases. Portugal wrestles with most of the same problems as other affected countries--treatment, social impact, and prevention. A sign of the times appeared recently in a series of articles published in Lisbon's leading daily, *Diario de Noticias*. One article, an interview with an attorney from the Public Prosecutor's office, dealt with the potential criminality of intentionally infecting an individual with an HIV virus. A second treated recent condom sales by a Portuguese manufacturer (up by 15 and 17 percent in 1986 and 1987, respectively, but down inexplicably by 8 percent in 1988). The last, an interview with a hospitalized homosexual AIDS victim illustrated the ability of the deep-rooted family-oriented nature of Portuguese society to overcome ultimately not only the stigma of AIDS, but also the more ingrained aversion to homosexuality and to rally to the support of family and friends struck by the disease.

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